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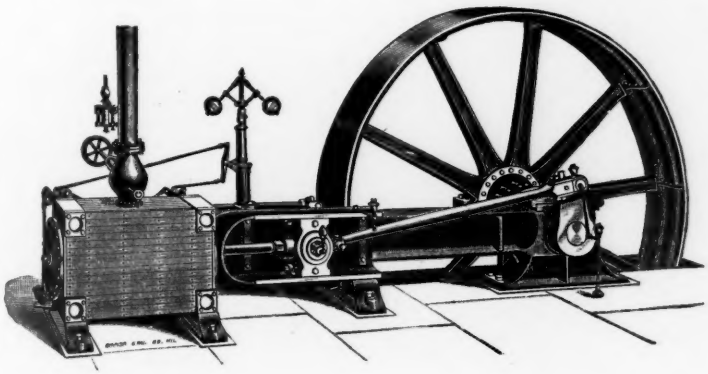

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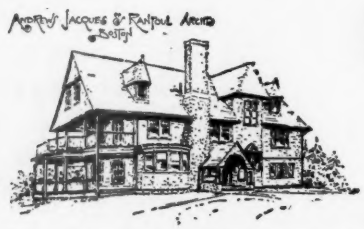

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TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. V. APRIL AND JULY, 1892. NOS. 1 AND 2.

PROCEEDINGS OF THE SOCIETY OF ARTS.

THIRTIETH YEAR, 1891–92.

THURSDAY, October 8, 1891.

THE 419th meeting of the SOCIETY OF ARTS was held at the Institute this day at eight P.M., President Walker in the chair.

The records of the previous meeting were read and approved. The President then introduced Capt. A. H. Russell, of the Ordnance Department, U. S. A., who read a paper on "The Construction of Modern Breech-Loading Rifled Mortars." The paper was illustrated by several lantern slides, and is published in full in the present number of the *Quarterly*. An interesting discussion followed the reading of the paper, after which the President extended the thanks of the Society to Captain Russell for his valuable paper, and declared the meeting adjourned.

THURSDAY, October 22, 1891.

The 420th meeting of the SOCIETY OF ARTS was held at the Institute this day at eight P.M., Mr. G. W. Blodgett in the chair.

The records of the previous meeting were read and approved, and the Chairman then introduced Mr. H. C. Spaulding, of the Thomson-Van Depoele Electric Mining Co., who read a paper on "Commercial

Electricity." The paper was illustrated by numerous photographs and is published in full in the present number of the *Quarterly*. The Chairman extended the thanks of the Society to Mr. Spaulding. The meeting was then adjourned.

THURSDAY, November 12, 1891.

The 421st meeting of the SOCIETY OF ARTS was held at the Institute this day at eight P.M., Hon. J. A. Dresser in the chair.

The records of the previous meeting were read and approved, and the Chairman then introduced Prof. Cecil H. Peabody, of the Institute, who read a paper on the "Triple-Expansion Experimental Engine in the Engineering Laboratories of the Massachusetts Institute of Technology." The paper was illustrated by several lantern slides, and is published in full in No. 3 of Volume IV of the *Quarterly*. After some discussion the meeting was adjourned.

THURSDAY, December 10, 1891.

The 422d meeting of the SOCIETY OF ARTS was held at the Institute this day at eight P.M., Mr. H. M. Howe in the chair.

The records of the previous meeting were read and approved. Mr. Frank B. Howell, of Charlestown, was duly elected an Associate Member of the Society. The Chairman then introduced Prof. William T. Sedgwick, of the Institute, who read a paper on "Milk Supply and the Public Health." The paper is published in full in No. 4 of Volume IV of the *Quarterly*. The meeting was then adjourned.

TUESDAY, December 29, 1891.

The 423d meeting of the SOCIETY OF ARTS was held at the Institute this day at eight P.M., Prof. C. R. Cross in the chair.

The records of the previous meeting were read and approved. The Chairman then introduced Mr. Francis R. Hart, of the Massachusetts Electrical Engineering Co., who read a paper on "Long Distance Transmission of Power by Electricity." The paper is published in full in the present number of the *Quarterly*. After a short discussion the meeting was adjourned.

THURSDAY, January 14, 1892.

The 424th meeting of the SOCIETY OF ARTS was held at the Institute this day at eight P.M., Prof. William T. Sedgwick in the chair.

The records of the previous meeting were read and approved. The Chairman introduced Mr. S. R. Koehler, of the Museum of Fine Arts, Boston, who began a paper on "The Photo-Mechanical Processes." Adjourned.

THURSDAY, January 28, 1892.

The 425th meeting of the SOCIETY OF ARTS was held at the Institute this day at eight P.M., Mr. Thomas Gaffield in the chair.

The records of the previous meeting were read and approved. Messrs. William Atkinson, of Brookline, and Eliot L. Caldwell, of Boston, were duly elected Associate Members of the Society.

Voted, that the President be authorized to appoint a committee of the Society to confer with a committee of the Corporation to consider the advisability of combining the publications of the Society of Arts and the *Technology Quarterly*. The President subsequently appointed Mr. George O. Carpenter, Col. E. H. Hewins, Professor Lanza and the Secretary to serve on that committee. The Chairman then presented Mr. S. R. Koehler, who continued the reading of his paper on "The Photo-Mechanical Processes." Adjourned.

THURSDAY, February 11, 1892.

The 426th meeting of the SOCIETY OF ARTS was held at the Institute this day at eight P.M., Prof. William T. Sedgwick in the chair.

The records of the previous meeting were read and approved. The Chairman then introduced Dr. James J. Putnam, of Boston, who read a paper "On Some Recent Discoveries and Problems in the Anatomy and Physiology of the Brain." An abstract of the paper is published in the present number of the *Quarterly*. The paper was illustrated by numerous lantern views, diagrams and models. Some discussion followed the reading of the paper. After the thanks of the Society had been extended to Dr. Putnam, the meeting was adjourned.

THURSDAY, February 25, 1892.

The 427th meeting of the SOCIETY OF ARTS was held in the Walker Building this day at eight P.M., Mr. George Jackson in the chair.

The records of the previous meeting were read and approved. The Chairman then presented Mr. S. R. Koehler, who concluded the reading of his paper on "The Photo-Mechanical Processes." After the thanks of the Society had been extended to Mr. Koehler, the meeting was adjourned. Mr. Koehler's paper will be published in a later number of the *Quarterly*.

THURSDAY, March 10, 1892.

The 428th meeting of the SOCIETY OF ARTS was held at the Institute this day at eight P.M., President Walker in the chair.

The records of the previous meeting were read and approved. The President then introduced Mr. T. C. Martin, of New York, who read a paper on "The Hollerith Electric Census System." An abstract of the paper is published in the present number of the *Quarterly*. At the close of the paper the President introduced Mr. Hollerith, of Washington, D. C., who exhibited in operation his machine for tabulating statistics by electricity. On motion of Professor Swain, a vote of thanks was extended to the speakers for their interesting exhibition. The meeting was then adjourned.

THURSDAY, March 24, 1892.

The 429th meeting of the SOCIETY OF ARTS was held at the Institute this day at eight P.M., Mr. G. W. Blodgett in the chair.

The records of the previous meeting were read and approved. The Chairman then introduced Prof. R. H. Richards, of the Institute, who exhibited and described "A Hand-Telescope for Stadia-Work." At the close of Professor Richards' remarks the Chairman introduced Mr. Harvey S. Chase, of New York, who read a paper on "Magnetic Concentration of Iron Ore." At the close of the paper Mr. Chase exhibited a machine in operation, which was watched with much interest. Both papers are published in full in the present number of the *Quarterly*. The Chairman extended the thanks of the Society to Mr. Chase for his exhibit, and declared the meeting adjourned.

THURSDAY, April 14, 1892.

The 430th meeting of the SOCIETY OF ARTS was held at the Institute this day at eight P.M., Mr. H. M. Howe in the chair.

The records of the previous meeting were read and approved. The Chairman then introduced Prof. Jerome Sondericker, of the Institute, who gave "A Description of Some Repeated Stress Experiments." The paper is published in full in the present number of the *Quarterly*. After Professor Sondericker's paper the Chairman introduced Prof. Dwight Porter, of the Institute, who described a "Pitot Tube for Measuring the Velocity of Water in Jets." After a short discussion the meeting was adjourned.

FRIDAY, April 29, 1892.

The 431st meeting of the SOCIETY OF ARTS was held at the Institute this day at eight P.M., President Walker in the chair.

The records of the last meeting were read and approved. Hon. J. A. Dresser, Messrs. J. P. Munroe and George Jackson, and Professors G. F. H. Markoe and William T. Sedgwick were appointed a committee to nominate officers for the ensuing year, to be elected at the next meeting.

Col. E. H. Hewins reported for the committee appointed to confer with a committee of the Corporation on the advisability of combining the publications of the Society and the *Technology Quarterly*, that they recommended the consolidation. Prof. William T. Sedgwick stated for the Faculty of the Institute that they deemed it advisable to unite the two publications, provided that the new publication is conducted by the Society of Arts.

Voted, to accept the report of the Committee.

Voted, to adopt the report, and to refer the matter to the Executive Committee, with power to make the arrangements necessary to carry out the plan.

The President then introduced Prof. C. H. Levermore, of the Institute, who read a paper on "Primitive Customs and Ceremonies of Marriage." The meeting was then adjourned.

THURSDAY, May 12, 1892.

The 432d and annual meeting of the SOCIETY OF ARTS was held at the Institute this day at eight P.M., Prof. William T. Sedgwick in the chair.

The records of the previous meeting were read and approved. The Nominating Committee reported the names of the following gentlemen for Executive Committee for the ensuing year: George W. Blodgett, C. J. H. Woodbury, Henry M. Howe, George O. Carpenter, and Charles E. Powers. These gentlemen were then duly elected members of the Executive Committee. Mr. Blodgett reported from the Executive Committee that, to their great regret, the present Secretary declined renomination, and that they recommended Mr. C. W. Andrews for Secretary for the ensuing year. Mr. Andrews was then duly elected. The annual report of the Executive Committee was read, accepted and placed on file. The report of the Meteorological Committee was read, accepted and placed on file, and it was voted that the committee be continued.

The Chairman introduced Dr. H. P. Bowditch, of the Harvard Medical School, who read a paper on "Anthropometry in the Public Schools." The paper was illustrated by the lantern. A short discussion followed the reading. On motion of Mr. Dresser it was voted that the warm thanks of the Society be extended to Dr. Bowditch for his very interesting and instructive paper. The meeting was then adjourned.

THURSDAY, May 26, 1892.

The 433d meeting of the SOCIETY OF ARTS was held at the Institute this day at eight P.M., Mr. G. W. Blodgett in the chair.

The records of the previous meeting were read and approved. The Chairman then introduced Mr. W. J. Salomon, of Newark, N. J., who read a paper on "The Theory and Practice of Tanning." The paper is published in full in the present number of the *Quarterly*. The thanks of the Society were extended to Mr. Salomon, and the meeting was then adjourned.

LINUS FAUNCE, *Secretary.*

THE CONSTRUCTION OF MODERN BREECH-LOADING RIFLED MORTARS.

By Capt. A. H. RUSSELL, U. S. A.

Read October 8, 1891.

The new use of mortars for coast defence was ably discussed before your society, last winter, by Colonel Mansfield, of the Engineer Corps of the Army, and it will be unnecessary to dwell particularly on this point.

We have, however, many important things to consider regarding the manufacture of these engines of war, and this paper will be confined mainly to that subject. Experience with the castings made for thirty mortars at Providence, and a number here, gives, too, some valuable data regarding the Rodman process of casting, and throws some light on the question of using cast iron in the construction.

The modern mortar, shown in longitudinal section in Figure 1, presents little likeness to the apothecary's mortar, which suggested the name for the old type, given in Figure 2, showing on the same scale the old muzzle-loading, cast-iron mortar of 13-inch caliber.

The new mortar has more the size and proportions of a gun, as is seen by Figure 3, giving the outline of a 15-inch Rodman gun, on the same scale. Its right to the name of mortar comes only from its similarity of use for throwing shells high into the air to reach, from above, objects like the deck of a vessel that could not be hit by the direct fire of high-power guns; the latter being effective only against the sides of the vessel. In shape it is a large howitzer, rather than a mortar; but being used like the old mortar for firing at much higher angles than was common with the old shell-cannon called howitzers, it is called in this country a mortar, though often designated a howitzer abroad.

While the old mortar was a short, smooth-bore, muzzle-loading piece, throwing a spherical shell, the new mortar is a breech-loader 129 inches long, nearly as long as the old muzzle-loading Rodman

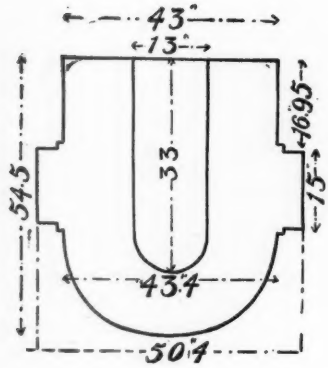


Fig. 2.
Old 13-inch Mortars.

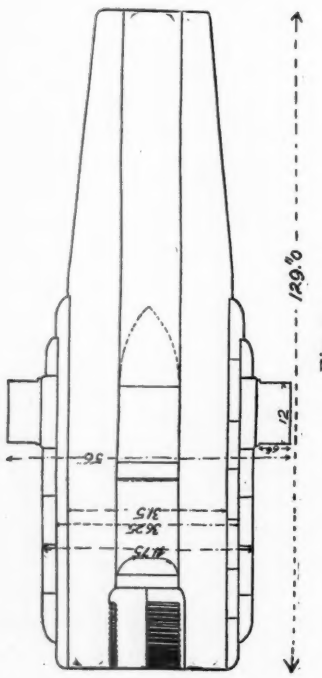


Fig. 1.
Longitudinal Section of 12-inch Breech-Loading Rifled Mortar.

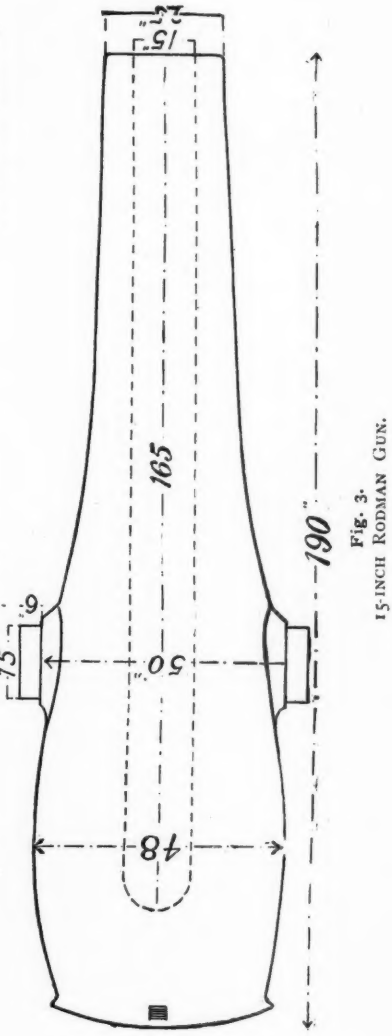


Fig. 3.
15-inch Rodman Gun.

gun, and rifled in the bore to make it possible to throw an elongated projectile (indicated in outline in Figure 1, in the firing position, nearly midway in the piece). The rotary motion given to the projectile by the twist of the rifling is necessary to keep the point of the shell in the direction of flight, much as the spinning of a top is necessary to keep it balanced on its peg. Going point on, the shell encounters less resistance from the air than if moving sidewise, and presents to this resistance a section no greater than the caliber, as with a round ball, while the added weight due to its length gives it greater inertia to maintain its velocity, and causes it to carry further than the round ball. A closer fit in the bore, too, is practicable with the long shell, as a copper band encircles the hard metal of the shell, and wedges into the rifling grooves, securing greater uniformity of motion in leaving the piece, and thus greater accuracy of fire.

The new piece, instead of being fashioned from a single piece of metal, like the Rodman gun, is, like the modern high-power guns, "built up;" *i.e.*, a central tube is encircled by hoops of steel, shrunk on so as to give a strength not practicable with the solid gun. Figure 1 shows these hoops in section. Illustration is given in Figure 4 of the principle on which this construction is based, as drawn from the law first worked out by Barlow for the resistance of hollow cylinders to pressure from within. The inner ring (shaded heavily) represents the section of a tube with walls equal in thickness to the bore. Suppose this to be enlarged by pressure from within until the bore gains the size of the original exterior. Assuming that the metal maintains the same volume, the exterior shaded ring shows the new section; and while the inner circumference is enlarged three times, the outer circumference is enlarged but little more than one and one third times, showing

Fig. 4.
EXPANSION OF HOLLOW CYLINDERS.
Illustration of Barlow's Law.

that the strain on the inner metal is much greater than on the outer, as is evident from mere inspection of the figure. The law deduced is that the strain communicated to the metal varies inversely with the square of the distance from the axis. The inmost layer, therefore, might reach its breaking point before the outer metal, and a crack might be started within, which would tear outward so that the tube would rupture before the full strength of the outer metal had been brought into play.

If, however, each layer progressing outward were originally stretched slightly more than the one within, it is evident that the inner layers would be more supported by the outer layers against internal pressure, and the full advantage would be obtained when these strains were so proportioned that the layers would reach their limit of elasticity at the same instant. Then the tube would stand a much higher internal pressure than before. A tube so constructed with walls half a caliber thick (indicated by the dotted circle) would be one and one half times as strong as a ring of homogeneous metal a full caliber thick. Such a construction will evidently bring the inner layers into a state of compression; and this is a decided advantage, as they then can be expanded more before breaking than if in their normal condition.

This law of Barlow, so familiar to scientists, would hardly need to be recalled were it not that it is frequently asked, even now, why we should not make guns of one piece. In practice, the law of variation of strain is more complicated than that given by Barlow, too much so for me to undertake its discussion now. Its application to army gun construction has been ably made by Captain Birnie, of the Ordnance Department of the Army; but the old law, approximately correct, gives a striking illustration of the disadvantage of the solid gun; for, though such initial strains as are described can be produced to some degree in cast iron, yet they cannot be as fully controlled as in the "built-up" guns.

While the ideal of tangential strength is secured more fully by wire wrapping, in which each layer is very thin, difficulties encountered in giving sufficient longitudinal strength by this method of construction have delayed its adoption, and the usual practice is to secure the desired condition, approximately, by the use of successive layers of hoops, made as thin as the conditions of manufacture allow, the great multiplication of very thin hoops being found undesirable.

In these mortars we have almost the only remaining example of the use of cast iron as a part of the system; for, while the modern high-power rifled gun is made up wholly of steel, the inner tube or body of the mortars is of cast iron. The high pressures and strains in the larger guns put the use of cast iron out of the question for them; and even for mortars the all-steel construction presents some decided advantages, since by it a more powerful piece of less weight can be obtained.

In Figure 1 the shape of the cast-iron body is shown, with bore extending through and fitted at the rear with slotted screw threads to hold the screw breech-piece. This body is cylindrical at the rear for over half its length, with a slight shoulder at the front of this portion to prevent slipping backward through the hoops, and a taper thence to the muzzle.

Over this cylindrical portion the figure shows, first, a row of seven hoops. The front hoop has a shoulder at the front, corresponding in use to the shoulder on the body. Outside this row of hoops is another row of six hoops, completing the envelope. One of these outer hoops, the second from the front, carries the trunnions, as shown in the figure. The hoops of each row are shrunk on, so producing the desired strain on the inner metal. Difficulties of construction make it desirable to use several short hoops in place of one long hoop or jacket.

The steel hoops, and other steel parts, are made at the Midvale Steel Works, Philadelphia, and sent, roughly shaped to size, to the contractors for finishing; forty-three mortars being under contract at the South Boston Iron Works, and thirty at the Builders Iron Foundry, Providence. These, with two or three more already built, are all for which Congress has made appropriation, out of the eight hundred needed for our coast.

Beside the steel hoops there are steel parts furnished which go to form the breech mechanism. This is of the interrupted-screw type, commonly known as the French, but really the invention of Chambers, an American.

A full screw is cut on the cylindrical breech block, and then the screw threads are cut away parallel to the axis of the block at three points, leaving three spaces plain and three threaded, equal in width. The recess in the breech has screw threads similarly cut and slotted; so that when the threaded sections of the block are opposite the

slotted sections of the breech, the block can be pushed in. Then one sixth of a turn engages all the threads. The threaded portion, of course, has to be longer than if the full thread were used, but in the latter case the block would have to be turned a great many times to screw it home. When pulled out, the breech block rests on a hinged tray, which swings to one side, uncovering the breech for loading.

The hoops are bored to a definite size, then the cast-iron tube or body is turned to a diameter about five one hundredths of an inch larger than that of the interior of the small hoops. These hoops are expanded by heat until they will slip over the body. They are put on from the rear, singly, and cooled in place; then they are turned off on the exterior with reference to the larger hoops, and the latter are applied in like manner. The front hoop of each row is forced forward to the shoulder, and the rear hoops are forced as close as possible to those in place, in order to make a continuous envelope.

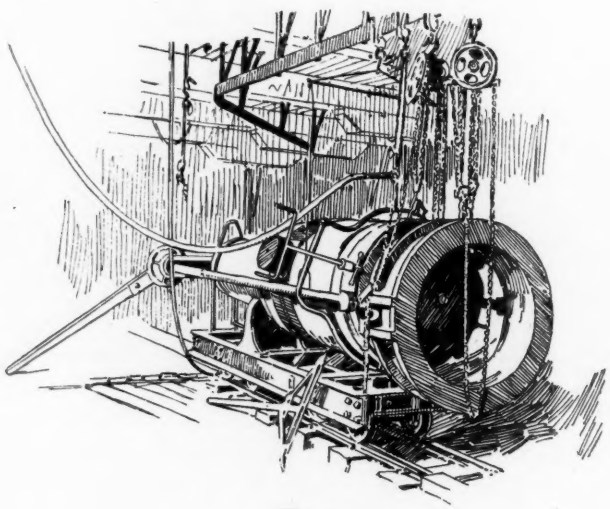


Fig. 5.

OPERATION OF HOOPING MORTARS.

The application of each row of hoops contracts the bore of the cast-iron body six to eight one thousandths of an inch, although the thickness of the walls is nine and one half inches.

By means of the star gauge the original diameters of the bore are measured at short intervals throughout the length, and remeasure-

ments are made after each row of hoops is applied. The instrument is constructed as follows: Through a brass tube runs a sliding rod, having at the rear end a handle bearing a scale, by means of which, with a vernier on the rear end of the tube, the inspector can read off the movement of the rod. The front end of the rod terminates in a cone, and as it moves forward it presses outward two or three measuring points, arranged radially with reference to the axis, and made to slide through holes in a head attached to the front end of the tube. The instrument is first tried in a gauge-ring of the proper size, and a reading is taken. Then this operation is repeated in the bore, and the difference of reading gives the variation in size from that of the ring.

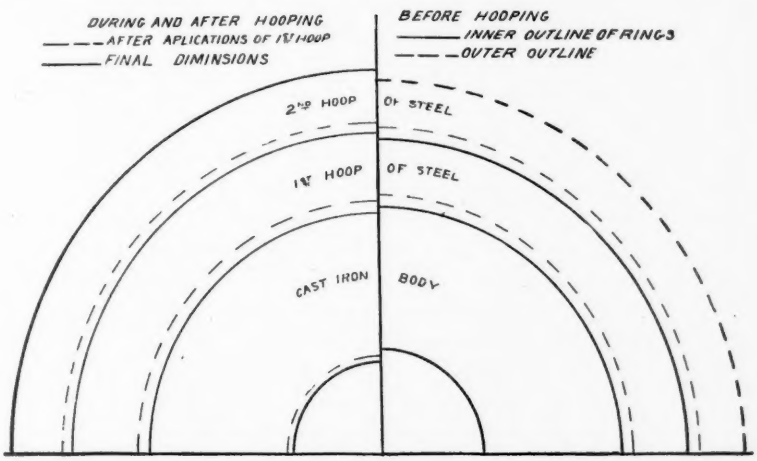


Fig. 6.

EFFECT OF HOOPING.

The hoops are heated in a gas furnace to a temperature not greater than 500 to 600° F. above the temperature of the shops, higher temperature being avoided in order to prevent all formation of scale on the interior. This expands the hoop enough to give a play of about five one hundredths of an inch in slipping on the mortar. When the hoop is in place it is clamped securely to the front of the piece by long side bars, drawn up powerfully by hydraulic or screw pressure, and a spray of cold water is at once driven against the outer surface to cool it.

The hoop is cooled at the front first, in order that it may nip there

before it nips at the rear, as otherwise it might shrink away from the front hoop in cooling and leave a wide joint. The clamps are drawn tighter and tighter as the hoop cools, and they are released only when the hoop is firmly shrunk in place. Then another hoop is heated and put on.

Figure 5 shows the apparatus for hooping, the mortar being horizontal during the operation.

Figure 6 illustrates the different steps in the operation of hooping. In the portion to the right the figure shows the sizes of the body and the hoops before they are assembled; in the portion to the left, the effect produced by applying the hoops. By the application of the small hoop to the body, the body is compressed and the hoop enlarged. By the application of the larger hoop the body is still further compressed, the small hoop is reduced in size, but not quite to its original dimensions, and the outer hoop is enlarged.

Figure 7 shows the construction of the mold for casting by the Rodman process of cooling from the interior, a current of water flowing through a hollow core. The mold forms a cylindrical cavity about sixteen feet deep, and the usual hollow core of the Rodman process runs down through the center. A pipe from above runs down within the core nearly to the closed bottom, and supplies a stream of cold water which flows up within the core, outside the pipe, and off by an escape-pipe above. The metal stiffens enough in about twenty-four hours to allow removal of the core. The water is then admitted into the hole itself, though the metal of the casting is still at a red heat. The clay cover of the core is left in when the core is drawn out, and this forms a protective lining to the cavity to prevent excessive chilling of the metal. The figure shows the core extending only part way to the bottom, with the mold following nearly the contour of the cannon; but the present practice is to make the casting cylindrical, and as the mortars are breech-loading, the core extends clear through to the bottom of the mold, where it is stepped into a depression, a pot of cast iron being sunk in the sand at the bottom of the mold, with the edge slightly projecting, so that the molten metal comes in contact with the edge, and forms a joint tight enough to keep the water from escaping after removal of the core. The metal flows down through runners in the sand of the mold, and runs in first at the bottom, side gates from the runners admitting it higher up as the mold fills. These openings

are set oblique to the radius, to give a swirling motion to the metal in the mold, this making it easier to keep the impurities from sticking to the sides.

About twenty tons of pig iron and scraps of former castings are melted and poured in this operation, the reverberatory furnace being used. The cooling takes from seventy to eighty hours. A fire is kept up in the pit outside the mold to check the cooling of the exterior.

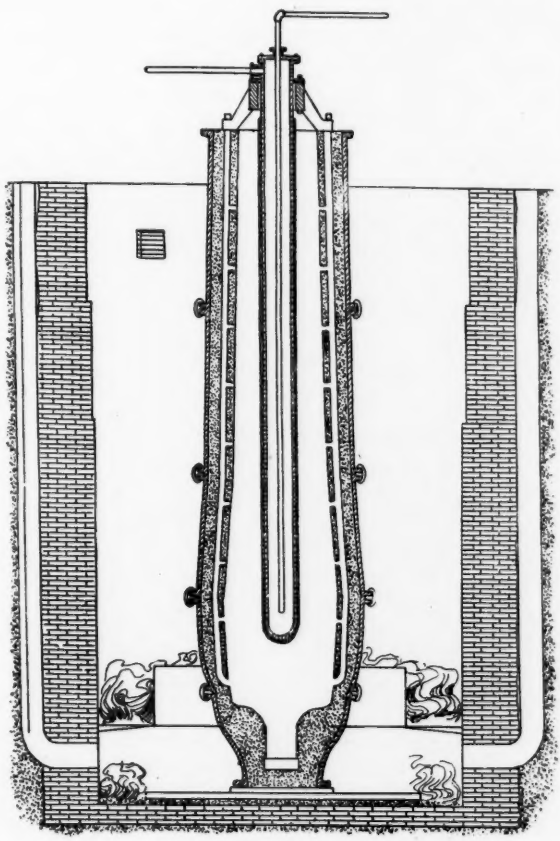


Fig. 7.

PIT AND MOLD READY FOR RODMAN CASTING.

Figure 8 shows the appearance of the casting when removed from the mold. It is a cylinder about thirty-four inches in diameter and fifteen and one half feet long, with a rough bore about ten and one half inches in diameter. The workman is represented as cleaning off the exterior.

The casting is made cylindrical to secure an approximately uniform strain of cooling throughout the casting. A length of about three feet is cut from the top, and five to nine inches from the bottom, or breech end, leaving room between for the body. This middle part is bored out and turned down to the proper size, tapered off at the muzzle, the weight being reduced to about eight tons.

Fig. 8.
APPEARANCE OF CASTING WHEN TAKEN FROM THE MOLD.

The effect of cooling from the interior is to produce a compression of the metal near the core, and an extension of that near the outer surface, this effect depending on the rate of cooling, or the rate of flow of water through the interior. Exactly at what stage of cooling this effect is produced most extensively is not yet determined; but experiments are in progress to determine this, and to find by means of a new thermo-electric pyrometer the time when the molten metal stiffens. It is probable that the greatest effect is produced soon after the

metal stiffens, when the water flows into the hollow itself, the surface exposed to cooling being much greater than when the flow is through the core. The theory is that the metal nearest the core stiffens first, and that the outer layers, forming later, and having to contract more in cooling than the partly cooled metal within, must compress the interior layers. Evidently it will be impossible for the outer layers to shrink the normal amount, and they will be stretched like the outer hoop shown in Figure 6. The metal close to the exterior, however, which may stiffen earlier from radiation of the heat to the outer walls of the mold, seems to show a reversal of these strains. This outer skin is turned off, and measurements of tension are made only on the layers corresponding to the inner and outer ones of the finished body.

Test disks, shown in Figure 9, are cut from the castings close to the top and bottom ends of the body; and the three rings there shown, having a section of one square inch, are removed from the disks, the diameters of these rings being measured before and after removal.

The inner ring at the breech must expand enough to indicate an original compression at the bore of from 5,000 to 9,500 pounds per square inch; and the outer ring must contract, the strain of the exterior iron usually being about 4,000 pounds per square inch. Only a small ring is removed from the muzzle end, and this must indicate a compression lying between 5,000 and 13,000 pounds per square inch, the initial tension being usually greater near the top than near the bottom. The reason for this difference is not clear; but it may be due to greater heat at the top of the pit, outside the mold, than at the bottom, allowing less exterior cooling of the casting at the top.

Figure 10 shows a disk taken from the muzzle end of one casting, and cut into eight successive rings. At the right the curve of strains is shown, the distances below the horizontal line indicating compression, and those above indicating extension, the neutral point being just outside the third ring from the bore. It is to be noted that the outmost ring shows the reduction of strains mentioned above. It appears undesirable, therefore, to leave the outer skin on a finished gun casting, as a line of weakness may be expected a little below the surface.

The old method of determining initial tension was to cut the entire disk through radially at one point, as at the horizontal line, for

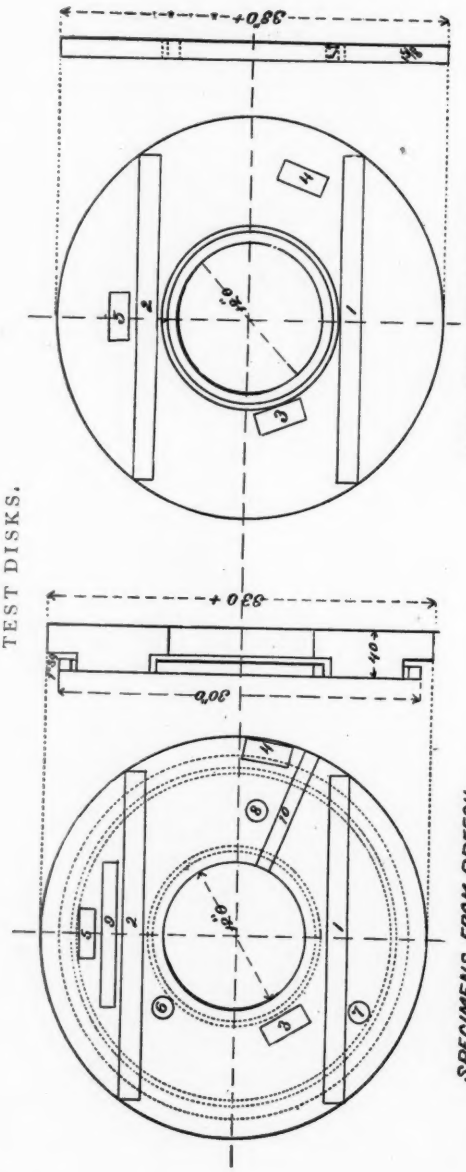

SPECIMENS FROM MUZZLE
Nos 1 and 2 Tangential Extension
" 3 4 " 5 " Tenacity
SPECIMENS FROM BREECH
Nos 1 and 2 Tangential Extension
" 3 4 5 " Tenacity
" 6 7 & 8 Longitudinal "
No 9 Tangential Compression
" 10 Radial

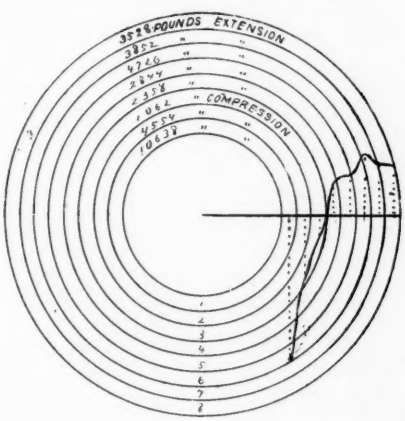
Fig. 9.
TEST DISKS.

instance; and to calculate the tension by the variation in the opening from the width of the original cut. Inspection of the strains indicated in the diagram shows that the variation in the radial slit in the old method gives merely the resultant effect of many varying strains throughout the disk, and no data for calculation of the strain at any particular point of the disk.

The old theory was that the strain of extension on the exterior was equal to that of compression at the bore; but new results show that the former is much less than the latter, and that proper measurement would give about half the compression supposed to exist at the bore in castings tested only by the old method.

Fig. 10.

STRAINS IN RODMAN CASTING.



DISTANCES BELOW HORIZOTAL LINE INDICATE COMPRESSIONS
DISTANCES ABOVE — — — EXTENSIONS

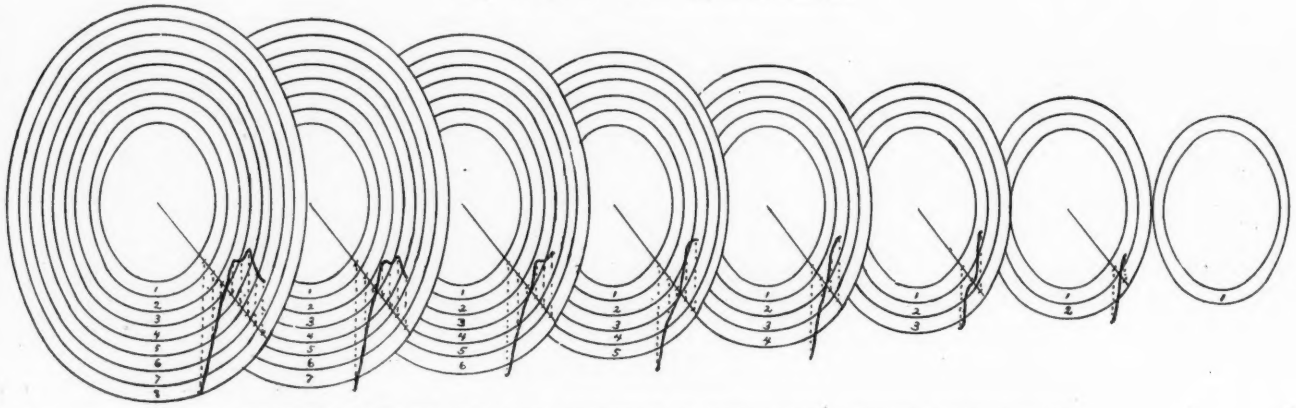
The new method is due to Captain Crozier, of the Ordnance Department of our Army, who, a few years since, at Watertown Arsenal, removed a full disk from a casting and cut it into rings, measuring the expansions and contractions; applying to cast iron methods used by General Mayevski in Russia, and later by Noble in England, for determining strains in steel hoops.

At Providence the process was carried a step further than by Captain Crozier, in that measurements of the rings were made, not

Fig. 11.

RODMAN CASTING.

Change of Strains as Outer Layers are removed.



DISTANCES BELOW OBLIQUE LINES MEASURED ON DOTTED LINES INDICATE COMPRESSIONS

DISTANCES ABOVE —— — —— — — — — EXTENSIONS

only before removal of any from the original disk, and after the separation of the rings, but in the disks of different sizes left by cutting off exterior rings. This made it possible to determine the tensions in disks of varying diameters, corresponding to the sizes at different points of the tapering muzzle. The result is given in Figure 11. This shows how the compression of the inner metal decreases as the outer rings are removed, except, perhaps, for the removal of the outmost ring. Also, how the neutral point remains just outside the third ring until the fifth ring is removed, when it shifts to a point between the second and third rings, and the third ring becomes stretched instead of compressed. A reversal again takes place when the third ring is removed, and the second ring becomes stretched in a disk of two rings, the neutral point lying between them.

These recent results of careful and suitable measurements bear out fully the theory of Rodman respecting the advantage of cooling cast-iron guns from the interior, and confirm his genius. Observing the opposite effect in solid cylinders, necessarily cooled from the exterior, where the inner metal tends to become spongy, being drawn outward by clinging to the outer layers, which stiffen first, he introduced the new method to secure sound metal near the bore, and to produce advantageous strains, the old method producing directly opposite strains. The effect of cooling from the exterior is particularly apparent in chilled rolls, which often break apart under the strains produced, and show cavities within.

Even cooling from the interior may be carried on so rapidly that excessive strains will occur, causing rupture at the outer surface; and this has been illustrated in many gun castings, which have burst asunder in the lathe, or even in the mold.

Though tests of specimens cut from the casting near the bore do not necessarily show an increased density, it is probable that the density is increased in the casting itself, the specimen when free recovering its normal size, not having been compressed beyond its elastic limit.

Figure 9 shows the muzzle and breech test disks marked off to show where specimens are to be taken for test: the long ones for elongation and compression, and the short ones for tenacity, density, and hardness. The latter are arranged at different distances from the center. No definite law of variation of tenacity has been found; but the lowest tenacity in any one disk is apt to be found in the middle,

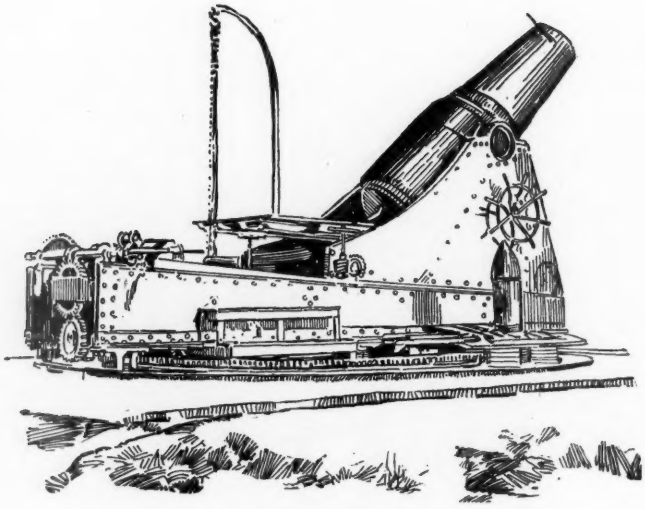


Fig. 12.

B. L. Mortar, old form of Carriage.

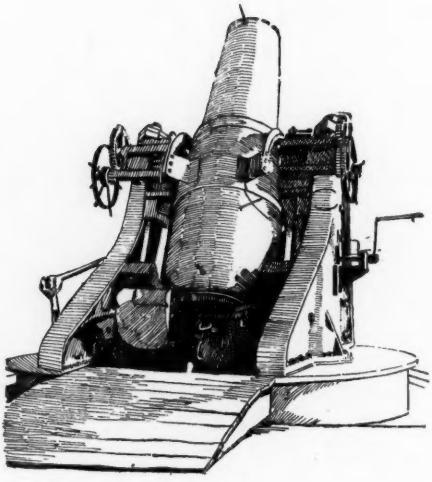


Fig. 13.

The 12-inch B. L. Mortar,

Mounted on the "Easton & Anderson" Carriage.

and the muzzle (near the top of the casting) usually runs higher than the breech. The head of metal seems to give very little advantage. There is the same lack of regularity in density and hardness, but the hardness is usually greatest at the top.

The tenacity must lie between 28,000 and 37,000 pounds per square inch, with an average of at least 30,000 pounds.

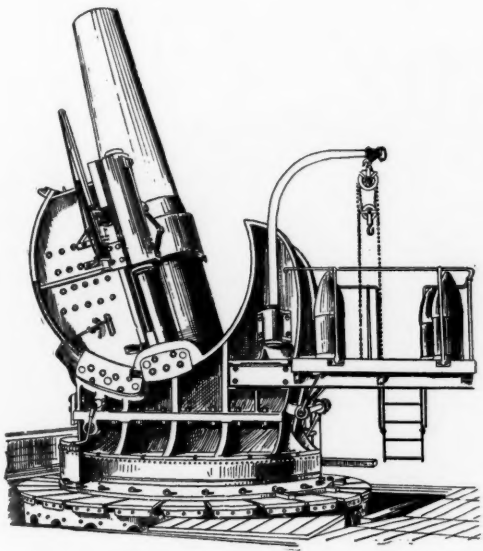


Fig. 14.

WHITWORTH MOUNTING FOR HIGH-ANGLE FIRE.

Figures 12 and 13 show the United States mortar mounted on its carriage; Figure 12, the old form of carriage, without provision for taking up the recoil; Figure 13, the modern carriage, described by Colonel Mansfield, where the recoil downward in an oblique direction is checked by hydraulic or pneumatic buffers. Figure 14 shows the Whitworth carriage with a mortar of English pattern. Figure 15 shows the old-fashioned mortar, mounted for firing.

In this connection it may be said that the old idea of the importance of great weight in cannon to lessen recoil does not apply particularly to mortars, since the methods for checking recoil and

reducing the shock on the carriage have been so fully developed. On the other hand, since the mortar has to be restored to its firing position by means of springs which are not required to bear the full effect of the recoil, advantage in reduced length of springs can be obtained by having a lighter mortar. This would be given by the all-steel construction now proposed, and at the same time a more powerful piece would be obtained, throwing a shell of eight hundred pounds six miles, instead of a shell of six hundred and thirty pounds five miles.

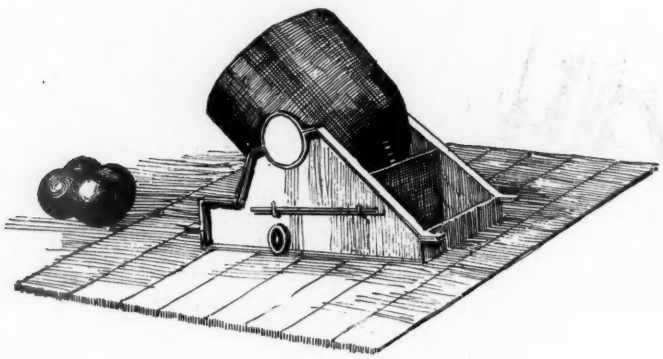


Fig. 15.
13-INCH SEACOAST MORTAR, SMOOTH BORE.

COMMERCIAL ELECTRICITY.

By H. C. Spaulding, S.B.

Read October 22, 1891.

In treating in an informal and brief way of some of the most interesting applications of electrical science which have come under my personal observation, as probably the greater proportion of manufacturing capital and of the time of our ablest inventors are now being devoted to the development of power apparatus rather than to that intended for lighting simply, I propose to give my attention principally to that branch of the science.

It may be well to note at the outset the misapprehension, which is more or less general on the part of the public, as to the scope of electrical power, so called. We very often hear references to the three things — steam power, water power, and electrical power. Of course it is hardly necessary before you to call attention to the fact that "electrical power" should rank rather with shafting and belting, than with the steam engine and the turbine. To be sure, we may get directly from the electric current lighting and heat effects; but for the purposes of our discussion the electric current is simply to be looked upon as a medium of transmission of mechanical energy, and for this very reason can be used economically only where the losses attendant upon the transformation of mechanical to electrical energy and back again will be less than the losses attendant upon the use of steam power or water power, and also where the expense of maintenance and interest on the plant would be less than the expense of fuel, in case the ordinary and more generally known methods were adopted. The limitations, aside from those just mentioned, come in the sizes of the power units delivered, the distance to which the power is to be transmitted, and again in our larger cities, or in communities where the population is compressed, if I may use that term, in the other considerations of convenience and the opinion or prejudice of the public in the place where the power is to be used or distributed.

My subject very naturally divides itself under three general heads of Generation, Transmission, and Utilization, or retransformation of

the electric current. Here again limitations are found, according as we are to use the current entirely for power purposes, entirely for lighting purposes, or partly for one and partly for the other; and again the sub-division as to whether we are using it for lighting large areas, the light being concentrated in different spots, as in the arc system, or for general distribution, as in the incandescent. Passing briefly, then, over the importance of having the generating plant so located and arranged as to get a regular and reliable power, and passing over, also, the construction of the lines, let us take up the third subject, that of the utilization or retransformation of the electric current into mechanical energy. We may start with the simplest form of electric motor, which is illustrated by the standard type manufactured by the Thomson-Houston Company. This motor illustrates very well the simplest form of dynamo-electric machine, either as motor or generator. The magnet is inverted, the ends being simply bored out to receive the armature. It has an ordinary shunt winding, and the whole machine is brought down to the simplest form of the motor and adapted to stationary uses for belting to shafting, and obtaining power in that way. Aside from the ordinary circumstances under which motors can be used exactly as steam engines would be, or other power generators that might be mentioned, such as gas engines, the tendency is to incorporate the motor with the machinery, which is to be run so as to make a complete mechanical unit. Where, a little time ago, we would have had the motor belted or geared to pumps and hoists, we are now more apt to hear them spoken of as electric pumps, electric hoists, etc.

Developing gradually from the primary type of motor to which we supply our electric current, and from which we take the mechanical energy by a belt, we have certain well-defined steps. First, the motor is simply belted to the shafting. Second, the motor is located on a swinging platform and clear of the floor, thus gaining one of the principal advantages of the motor by utilizing space, a feature possible with the electric motor, but not with ordinary engines, simply from the absence of reciprocating motion and "pound." The next step is in the omission of belting, the motor being geared directly to the shafting. This method of distributing power from an engine is rapidly coming to the front. A few large manufacturing concerns in the country to-day have adopted this method. Instead of carrying long lines of shafting for driving belts through their works, they have

placed a large engine at some point convenient to coal and water, running from this a battery of generators, and then distributing from their main lines the current as desired in different sizes. It may be interesting to some to get an idea of what a motor of 15 horse power will carry in ordinary shop practice. Such a motor will carry a 72-inch planer, an 84-inch planer, one 5-foot Warren radial drill, and a large double grinder. This motor was one of a system of about thirty motors running machinery in different parts of a large manufacturing plant from the same generating system, and driven by a large Corliss engine. Another motor of the same size (15 horse power rated, and this would be probably 25 or 30 per cent. under the actual running capacity), geared directly to the shafting so as to do away with belts, carried two 36-inch planers, two 32-inch planers, six 32-inch lathes, one 42-inch lathe, a 48-inch chucking machine, four 5-foot Prentiss radial drills, and a large double grinder. This motor, as I have said, was geared directly to the shaft, and was designed originally for railway work, and known as the single reduction type. In other words, the armature shaft carries a pinion instead of a pulley, which meshes directly with a large gear on the shaft, so that there is very little loss in mechanical transmission at this point.

Naturally the next step in the application of electric motors was in obtaining locomotion. Instead of the motor being stationary and the contact being permanent with the wires supplying the current, this contact was made movable, as we see it in our ordinary trolley street system; and the simplest trucks as used first were made by simply turning one of these stationary motors on its side and placing a pinion on the armature shaft, gearing back twice, owing to the high speed of the armature, the second reduction being with the gear placed on the axle of the car, this axle carrying one end of the magnet to this point, with possibly some springs introduced according to the designer, and the other end being hung in any desirable manner from the frame of the truck. Of course there have been, since that time, hundreds of modifications, some simply in shape and some in winding. The later ones do away with one set of gears, giving what is generally called the single reduction motor. The tendency, naturally, is here also to get the parts as heavy as possible within reasonable limits, and to protect the motor from accidental mechanical injury. In the Robinson radial trucks, which are in use on the West End road, the car is carried on six wheels, and the middle pair of wheels may move laterally in rounding curves.

We now come to the actual application of electric tramway motors to manufacturing processes as adopted in some of the mills, principally in New England, but also in other parts of the United States. The locomotive truck, or locomotive flat car, is, in its electrical features, very much like an ordinary passenger car, though some are much heavier, being designed for shifting as many as five or six loaded freight cars in and about a manufacturing plant, but also being used for carrying loads on its own platform. Others are of a good deal less capacity, in general 3 horse power, and are used for ordinary trucking purposes.

Up to this point these are ordinary applications of simple railway motors to mill tramways for manufacturing purposes. Motors as adapted to transfer tables have not been used to any great extent. I do not believe there are more than three or four in the United States at the present time. There is one at Cheyenne, Wyoming, which would stand as a type of all the rest. Probably one of the earliest transfer tables in the country was at Altoona, Pennsylvania. The Pennsylvania Railroad Company is devoting a good deal of time to the adaptation of electric motors to various purposes. The transfer table at Altoona is very long, having possibly a capacity for three freight cars of the usual size. The current is taken from copper strips which are placed along the under side of timbers parallel with the rails, the brush coming up underneath and rubbing along on these copper strips.

The first drawbridge to be operated by electricity was at Bridgeport, Connecticut; and, as was often the case in the early days of electric power, it required a great deal of demonstration to convince the authorities that it was possible to operate their drawbridge successfully and reliably by this method. People in general, in the early days of the motor business, seemed to think that electric currents were all very well to ring electric bells, and possibly to run sewing machines with; but not really, I think, until the adoption of electric motors on our street railways did the public generally come to appreciate sufficiently the power and possibilities of the force, and to believe that it could be as fully relied upon for power transmission as could line shafting, or a system of ropes or belts. The Rush Street drawbridge, at Chicago, has recently been equipped in a similar manner. At one of the large glass works at Pittsburg a motor has been applied to what might properly be called a transfer table, the glass in the melted state being poured out on a large metallic disk, and then being carried by this

transfer table to the rolls and polishing machines, under which it is treated. This truck is nine feet gauge, and contains some novel features. It displaced the endless rope system which was previously used. The rope had to be renewed about every six months, and was constantly giving trouble.

Of traveling cranes there is one of 20-ton capacity in the factory of the Thomson-Houston Company at Lynn, Massachusetts. Two very similar cranes are in the shops of the Blake Manufacturing Company at Cambridgeport. These cranes are among the few in the country at the present time (I think the first one was put in by the Pennsylvania Steel Company at Steelton) having three separate motors for three separate motions, one large motor being used for hoisting the load; a second for carrying the trolley back and forth on the bridge of the crane; and a third for effecting the motion of the bridge itself up and down the building. The power is supplied in the first place to two copper wires passing over insulated supports on each side of the building above the crane rails, the supports being placed at intervals, and the wire simply lying loose on them. As the bridge passes along, rollers affixed to it, at a sufficient height to clear the guides supporting the insulators, lift the wires, the positive being on one side of the bridge, and the negative on the other. The motor for giving the up and down travel in the building is connected directly with the trolley wire through these rollers. This motor in the 20-ton crane is 3 horse power. The other two motors are placed directly on the trolley. This crane is built by the Morgan Engineering Company, and is their regular type of girder. The trolley carries not only the hoisting motor on it, but also the motor for giving the cross travel on the bridge. The third motor, 3 horse power, is stationary as far as the bridge is concerned, and is placed at one end of it. The controlling levers are placed in a cage hung from one end of the bridge, and there is no mechanical connection between these motors and the drums. On the inside of one of the beams, insulated of course from it, are copper strips. Resting against these copper strips are carbon brushes, which take the current and carry it to the motor, and also down to the operator's cage. Each controlling handle operates a reversing switch and the rheostat for varying the speed of its motor. This crane that I have spoken of was the first crane to have no mechanical connection between the trolley and the controlling cage. The government has now in process of construction some three or four cranes on the same general principle.

Turning now to hoisting arrangements, one of the early types has the motor applied to the hoisting drum through double reducing gear. The pinions in this case, as in the early types of railway motors, were made of rawhide. Some modifications have been tried, such as rawhide and steel in alternate layers. Rawhide, I believe, is being produced by one or two firms by a new process, which is generally considered as meeting the requirements, although that is a point upon which opinions differ. A different type of hoist, with a winch head, is mounted on wheels so as to be portable. Several of these, I think nine or ten, are already in use, and others are being built for the steamship companies, it being a very convenient thing, and very economical as well, for use in unloading vessels. Power is needed at intervals only, so that any method by which it can be quickly obtained when necessary is very desirable. In a case that I have in mind the warehouses come up very near the dock, and along the front of the storehouse are placed service plugs similar to wall pockets for portable lamps, but carrying a current of greater power, and these hoists are moved about on the wharf precisely as donkey engines would be. The hoists are provided with flexible cables, and the plugs at the end fit into these sockets so as to leave as little slack cable as possible. The hoists of this type were designed principally for mining work, the first one being used to handle coal cars in a coal mine in Utah, where the railroad runs along in a valley with high mountains on either side; and a little way up on one of these is situated the coal mine, the vein running almost level, but being a little pitched down toward the slope. The cars are carried out through the tunnel and down the slope to the building in which the coal is picked over and cleaned. The whole plant in this mine is operated by electricity, the power being supplied by two Corliss engines, and used for hoisting the cars, which are run out in trips. They run down to the house, and the empty cars are pulled back at several times the speed that is possible by using mules. The power house is situated on the other side of the valley. Besides the hoist there are various ventilating fans at different points on the mine. The general plan is the same as in the small size, but the brake power is increased considerably, as would be necessary in such a case as this.

In the first part of the work of applying motors to elevator service a good deal of trouble was encountered, owing to the fact that at that time it was supposed to be inadvisable, not to say impossible, to stop

and reverse the armatures of the motors; and the first devices for running the elevators simply comprised the application of the power obtained from the motor to gears and open belt machines, just as gas engines or steam engines would be used, and of course involving the same objections as in any application of power to similar elevator apparatus. As the problem was studied into, and the electrical engineers found that motors could be stopped and reversed with perfect ease, the incorporation of the motor as a part of the mechanism resulted in some machines which are equal in smoothness of motion to hydraulic work. Several machines of this type are running in our large office buildings in Boston. The construction involves the use of worm gearing, the worm being placed over the worm gear on the drum shaft, with suitable brakes to control the mechanism, the rheostat and switch being placed in the car. One little piece of auxiliary apparatus is an automatic brake, which is perfectly simple in its general design. On the drum is placed a strap brake, and this brake is so arranged as to be held tight by a weight sufficient to operate it. Whenever the motor is in use in either direction, or, in other words, whenever the current is turned on, a solenoid coil is energized, the pull on its core overbalancing the effect of the weight on the brake strap. When the current is shut off to stop the elevator, the brake acts automatically as the solenoid is deënergized, and the weight again applies the brake. This device has also been applied to the traveling crane to hold the load whenever the current is shut off. While the direct acting electric elevator machine was being evolved, numerous devices were placed on the market for the application of electric motors to hydraulic elevating plants, some using a switch for starting and stopping the motor gradually as the water was needed, and others having the motor in operation all the time, and pumping the water from the supply tank into the pressure tank; and when the latter was full the valve was automatically opened, which allowed the water to run back from the pressure tank into the supply, so that the water was practically short circuited, and hardly any work was done.

In a type of pump which is perhaps specially adapted to electrical work the shaft carries three plungers placed at angles of 120° to each other, so that the motion is very even. There is no perceptible pull on the armature, and the water thrown out goes out in a very even stream. The results are very good. The pump is manufactured by the Gould Pump Company, at Seneca Falls, New York. The gearing

is double, the plungers single acting and vertical. A modification of this same type has the plungers in horizontal position; another interesting feature being that every section of the pump is like every other section; so that for mine work, if possibly half a dozen pumps are required, each of different capacity, instead of the entire half dozen differing in each part, every section is a duplicate of its corresponding part; so that one complete section kept on hand allows for repairs in case anything breaks. That is, one pump might be a triplex pump, another possibly a duplex, and another possibly a quintuplex pump, with five cylinders, each exactly like its neighbor and exactly like those in the other pumps. One of the largest or most powerful electric pumps yet built was designed for lifting 100 gallons per minute to a height of 1,500 feet. This is for deep mine work in the West. The pump part itself is of the ordinary Knowles mine pump pattern, but spread so as to take in the motor between the center lines of the cylinders. The armature shaft is coupled to what is really an extension of this shaft, carrying two worms, right and left-handed respectively. If only one worm were used to transmit the power to the main gear operating the connecting rods, we should have considerable end pressure on the armature shaft, which for obvious reasons it was desired to avoid. The method adopted for obtaining this result was in using the second worm, meshing with an idler, which also meshed with the large gear wheel just mentioned, thereby balancing the acting forces and doing away entirely with the end thrust on the armature shaft. In order to obtain the best possible lubrication the gears were surrounded by a cast-iron jacket filled with oil, and fitting so closely that the teeth of the gears acted as paddles conveying a continuous supply of oil to the worms. An "alleviator" takes the place of the ordinary air chamber, which, of course, under such tremendous pressure would not do the work, and consists of a number of cylinders of rubber which are compressed by the piston against which the water acts at this point. A twenty-four hours' continuous test of this pump gave results which were exceedingly satisfactory; the efficiency of the entire pump, that is, the ratio between the electric power furnished by the motor and the actual work on the water, being 74 per cent., which is exceedingly good, in view of the fact that worm gearing was used; but I attribute that to the fact that in an ordinary worm gear, unless rolls are used (and certainly I should not want to send roll bearings to that part of the

country), the end of the shaft will have the same surfaces continually in frictional contact, thus preventing thorough lubrication; whereas in this case this end thrust is taken away entirely, and by means of the second worm fresh bearing surfaces are continually presented.

I propose now to pass to some applications of electric machinery to mining processes. The first electric locomotive in the United States that I know of was in the Lykens Valley Mine, and was designed and built under Mr. Schlesinger, then of the Union Electric Manufacturing Company. Mr. Schlesinger is certainly entitled to a great deal of credit for being the first to introduce an electric locomotive in mining operations. The locomotive is now somewhat in the condition of the small boy's jackknife after it had a new handle and a new blade; but following that have come numerous modifications, which have gradually overcome the prejudice of mining engineers against the introduction of electricity in mines for this purpose. On the business side of this question of electric mine locomotion, it is interesting to note the difficulties which are met with in getting a good word from the mining men who have been benefited by the results of the work of the very machinery which it is desired to sell to their competitors. One mining man who adopted this method increased his output about 40 per cent., without increasing his running expenses at all. This he did by changing mule power for electric power for hauling coal. But a man doing that does not want his neighbors to adopt the same means, so that it is very hard to obtain recommendations from the men from whom you most desire them. The second electric locomotive that was built was for the Erie Colliery. One of the next types, and one which is attracting some attention from mining electrical engineers, is known as the "terrapin-back" locomotive. This locomotive weighs complete 21,600 pounds, is for a gauge of three feet, stands about three feet six inches clear from the rails, and handles anywhere from twenty to thirty mine cars at a time. The trolley is of special design, being simply like one section of the ordinary lazy tongs, and allowing for considerable variation in the height of the trolley wire. At the bottom of the two arms are placed gear sectors, so as to keep one side at the same height as the other; and adjustable springs give the tension at this point and keep the arms together, the trolley wheel being carried at the top of the parallelogram. Some improvements, which may not be of special interest to you, are introduced into the controlling mechanism.

A device which has attracted a good deal of attention of late is the reciprocating drill. The two principal experimenters upon it are Mr. Marvin, with the Edison Company, and Mr. Vanderpoele, with the Thomson-Houston Company. The drill consists of two or more solenoid coils, the core carrying directly the drill chuck which holds the drill at the lower end. Now the current is shifted by an arrangement on the commutator, and as it shifts the core is drawn from one end to the other, giving a reciprocating action to the drill. If this meets the expectations of its inventors, it will find a very great market in our deep mining operations in different parts of the country, since the electric current can be carried from the generator at the surface to the working face, that is, to the rock, with much less loss than by the compressed air system. The ordinary compressed air system used in our deep mines has only 30 or 40 per cent., on the average, of the initial power available at the point of operation, while such a device as this should have at least 60 per cent., and very often more under advantageous conditions. Very appropriately, one of the first applications of electric motors to mining operations was in the prospecting drill, used for bringing up a core of the ground to enable one to see whether it would pay to mine or not. In the Diamond prospecting drill the motor furnishes the power for rotating and feeding the drilling cylinder, and also pumps the water to the end of the drill.

Finally, for the measurement of commercial electricity the recording watt meter, so called, of Professor Thomson is now being manufactured for the various currents, 110, 220, and 500. It is exceedingly ingenious, the field coils being connected in series with the line, and the armature, which is placed on a vertical shaft, connected across so that the strength of the fields is governed by the quantity of the current, the strength of the armature by the voltage, and the resulting speed gives a very accurate measure of the quantity of the current passing through in a given time. The slow motion is obtained by the drag of a copper disk, working between the pole pieces of three permanent magnets; and the adjustment of the entire apparatus can be obtained by changing the distance of these magnets from the center of the disk as it revolves at this point. The number of revolutions is registered by ordinary clockwork, and readings are taken as from an ordinary gas meter.

LONG DISTANCE TRANSMISSION OF POWER BY ELECTRICITY.

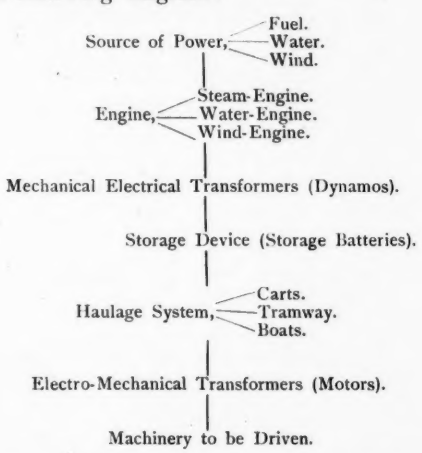
By FRANCIS R. HART.

Read December 29, 1891.

GIVEN a point where power is best obtainable, and another point where such power can be most advantageously used, the problem given to the engineer for solution is that of transmitting this power from the one point to the other. If the transmitting agent is electricity, the method is called one of *electrical power transmission.*

There are two general types of electrical methods that can be employed, (1) haulage, and (2) line transmission.

The first is comparable to the haulage of coal from the mine to a distant factory, there to have its stored energy utilized in mechanical work. The skeleton of such an electrical power transmission system is shown in the following diagram:

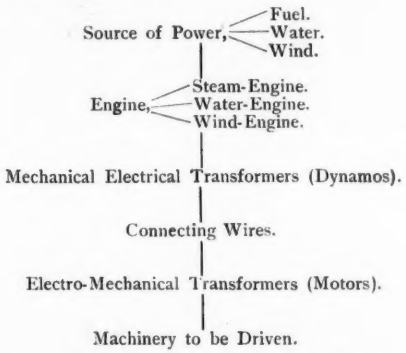


More analogous than the haulage of coal to this method would be a compressed air system. If the steam engine or turbine at the source of power drove air compressors which filled portable vessels

with compressed air, and these vessels were transported and attached to air engines at a distant point, we would have a system directly comparable with the electrical haulage plant.

The storage battery street car is an example of this method of electrical power transmission.

The other general type of electrical methods for distant delivery of power employs a line of conducting wires between dynamo and motor in place of the cumbersome system of haulage. The skeleton of this system is as follows:



The second system has obvious advantages for long distance transmission, and I shall consider with you that only. There are conditions, however, where even for other than tramway work the haulage system may be the only or best system that can be employed.

I have given *fuel*, *water*, and *wind* as the three power sources which may be employed to drive a power system. Some of the uses to which electrical methods of transmitting power may be put are shown in the following table:

Steam:	1. Large number small users obtain more economical power from one engine. 2. Local distribution from lighting companies. 3. Street railways. 4. To replace long shafts. 5. Special works (mines, etc.)
Water:	1. Locate mill with reference to shipping conveniences. 2. Concentration of small water-powers. 3. Carrying power into cities for factories, street railways, etc. 4. Continuous use of power (power during day, and lighting at night).
Wind:	1. Pumping (mines and irrigation); wind engine at best point, and pump anywhere. 2. Lighting with storage cells.

In practice, except for street railway and mining work, fuel is not an economical source of power for long distance transmission plants. Ordinarily it is cheaper to deliver the coal at the distant point and obtain the power directly. In connection, however, with water-power the usefulness of an electrical power system can hardly be exaggerated.

Before describing to you the various systems that can be employed for line electrical power transmission, I wish to call your attention to certain points concerning the efficiency of such a method, and how far we can govern this efficiency. We call the mechanical efficiency of a system the ratio of the power delivered to the dynamo-electric machines at one end of the line, to the power delivered by the electric motors at the distant end.

The commercial efficiency of a dynamo or motor, as I shall show you later, varies with its load. The maximum efficiency of good machines should not be under 90 per cent., and is seldom above 92 per cent. Under the most favorable conditions, then, we must expect a loss of, say 9 per cent. in the dynamo, and 9 per cent. in the motor.

The loss in transmission, due to fall in electrical pressure or "drop" in the line, is governed by the size of the wires, the other conditions remaining the same.

For a long distance transmission plant this will vary from 5 per cent. upwards.

With a loss of 5 per cent. in the line, the total efficiency of transmission will be slightly under 79 per cent.

With a loss of 10 per cent. in the line, the efficiency would be slightly under 75 per cent. We may call 80 per cent. the practical limit of the efficiency with the apparatus of today.

The methods for long distance power transmission by electricity may be divided into three general classes: (1) Those using continuous current; (2) those using alternating current; and (3) regenerating or "motor-dynamo" systems.

I have tabulated the subdivisions of each of these general classes, as follows:

CONTINUOUS CURRENT.

- 2-wire
  - Low voltage
    - One machine.
    - Machines in parallel.
  - High voltage
    - One machine.
    - Machines in parallel.
    - Machines in series.
- 3-wire
  - Two machines in series.
  - Machines in multiple series.
- Multiple wire
  - Machines in series.

ALTERNATING CURRENT.

- Alternating single phase
  - Without conversions.
  - With conversions.
- Alternating polyphase
  - Without conversions.
  - With conversions.

REGENERATING SYSTEM.

Alternating-continuous.

Continuous-continuous.

Partial reconversion of any system.

The relative advantages of these systems vary with each particular transmission problem, but in a general way may be tabulated as follows:

	System.	Advantages.	Disadvantages.
Continuous.	2-wire, Low voltage.	Safety, simplicity.	Expense for copper.
	2-wire, High voltage.	Economy, simplicity.	Danger, difficulty of building machines.
	3-wire	Low voltage at machines and saving in copper.	Not saving enough in copper for long distances. Necessity for "balanced" system.
	Multiple-wire . . .	Low voltage at machines and saving in copper.	Not saving enough in copper for long distances. Necessity for "balanced" system.
Alternating.	Single phase . . .	Economy of copper.	Cannot start under load. Low efficiency.
	Polyphase	Economy of copper, synchronous speed unnecessary; applicable to very long distances.	Complexity. Lower efficiency of terminal apparatus. Not as yet "standard" apparatus.
	Motor-dynamo . . .	High voltage transmission. Low voltage delivery.	Expensive. Low efficiency.

The system selected must, first, fill construction and operation conditions; and second, give minimum cost per horse power delivered. There are many factors which govern the selection of a system. For each problem considered there will be found certain fixed and certain unfixed conditions.

In general the fixed factors are as follows:

1. Capacity of source of power.
2. Cost of power at source.
3. Cost of power by other means at point of delivery.
4. Danger considerations at motors.
5. Operation conditions.
6. Construction conditions (length of line, character of country, etc.)

The partly fixed conditions are:

7. Power which must be delivered (*i.e.*, the efficiency of the system).
8. Size and number of delivery units.

The variable conditions are:

9. Initial voltage.
10. Pounds of copper on line.
11. Original cost of all apparatus and construction.
12. Expenses, operating (fixed charges, interest, depreciation, taxes, insurance, etc.)
13. Liability of trouble and stoppages.
14. Danger at station and on line.
15. Convenience in operating, making changes, extensions, etc.

Assuming that the cost of dynamos, motors, etc., will be approximately the same, whatever the initial pressure, I shall show you the great variation in the cost of wire at different pressures. For convenience in working out such problems for rapid and approximate determinations I have drawn a diagram or chart, Figure 1, from which can be determined the pounds of copper required for transmitting any number of horse power from one to twenty miles with an initial pressure of from 1,000 to 10,000 volts, at various losses in transmission. The scale of ordinates on the left gives the total pounds of copper required for one horse power for each mile transmitted, at 5 per cent., 10 per cent., and 20 per cent. loss in transmission. The scale of ordinates on the right gives the area in circular mils of one of the two necessary wires at the same percentage losses.

To illustrate the use of the diagram, suppose we wish to know the weights of copper required for transmitting 100 horse power five miles at 2,000, 3,000, and 10,000 volts, and at 10 per cent. and 20 per cent. losses respectively. By inspection of the diagram we obtain the following figures:

Voltage.	Drop. per cent.	Total Pounds Copper.
2,000	10	$33.6 \times 100 \times 5 = 16800$
	20	$16.8 \times 100 \times 5 = 8,400$
3,000	10	$14.8 \times 100 \times 5 = 7,400$
	20	$7.4 \times 100 \times 5 = 3,700$
10,000	10	$1.24 \times 100 \times 5 = 620$
	20	$.62 \times 100 \times 5 = 310$

Very interesting mathematical deductions can be made, showing conditions which give minimum cost, maximum efficiency, etc.; but

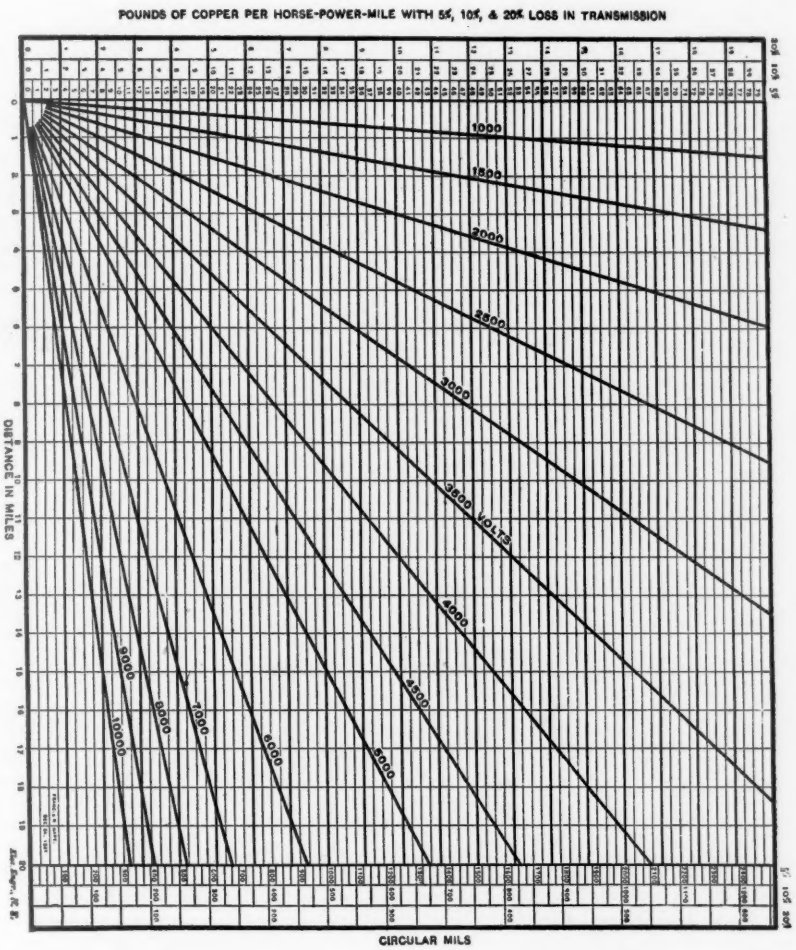


FIG. 1. LONG DISTANCE TRANSMISSION OF POWER BY ELECTRICITY.

in practice these become of small value, as almost invariably there are fixed construction or operation conditions which cannot enter as factors in a derived formula.

In the limited time left to me I can do no more than indicate to you the details of the construction and operation of an electrical power plant. I shall take as an example an installation where the source of power is water. We may separate the details of construction and operation into four heads — hydraulic, mechanical, electrical and financial. Under "hydraulic" come the improvement, control, and care of the water privilege; the selection, placing, and care of turbines, and the turbine regulation.

A good turbine, working at its proper load, will deliver from 75 to 80 per cent. of the total energy of the water. If over or underloaded to any extent, the efficiency is diminished. For the most efficient and economical working of a plant it is, therefore, necessary to exercise care and judgment in the management of the turbines.

Under the head of "mechanical" details of construction and operation belong the selection and care of shafting, gears, belts, clutches, etc. It is customary to so arrange the mechanical parts that any or all turbines or dynamos may be thrown into or out of use without affecting the running of the plant. That is, where possible, all like units should be interchangeable without interfering with the operation of the plant.

Under the head of "electrical" we have: line construction and maintenance; machine construction, installation, and maintenance; construction of switch board; selection, construction, and care of measuring instruments, lightning arresters, etc.; provision for extra parts of machinery, and conveniences for rapidly making necessary changes.

The same care exercised in keeping the turbines at maximum efficiency should be applied to the dynamos. The curve, Figure 2, shows the average variation in efficiency with load of dynamo-electric machines of from 25 horse power to 75 horse power.

In all such plants complete records, in the form of daily reports, should be kept of pressures, currents, speeds, heights of water, time machines are started and stopped, etc. A monthly statement should be made, showing the averages of the daily reports and all expenses for the month. It is convenient to deduce from each monthly statement, for a uniform basis of comparison, the cost per horse power delivered for a stated time.

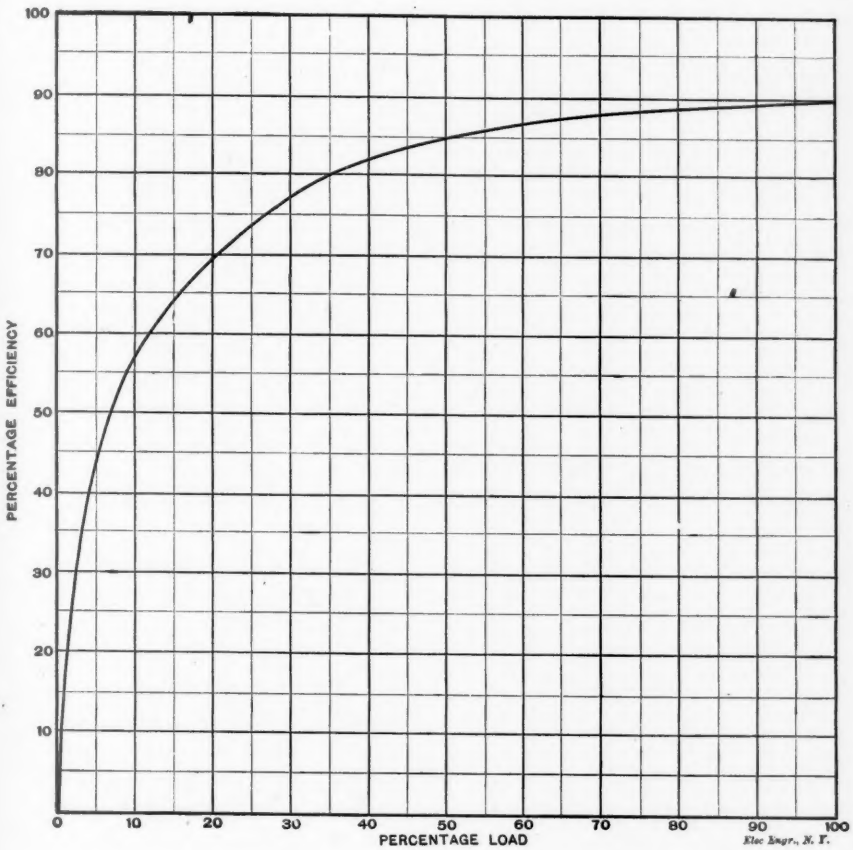


FIG. 2. LONG DISTANCE TRANSMISSION OF POWER BY ELECTRICITY.

ON SOME RECENT DISCOVERIES AND PROBLEMS IN THE ANATOMY AND PHYSIOLOGY OF THE BRAIN.

By JAMES J. PUTNAM, M.D.

Abstract of a paper read February 11, 1892.

Previous to 1870 it was thought that the whole brain acted as a unit, the physiologists of the day believing that they had ascertained through convincing experiments that when any portion of the hemispheres, at any rate, was injured, the functions of the brain suffered a general reduction, and that localized symptoms were not produced.

If one reads the books of the date of Longet, however, indications are noticeable that this opinion was felt to need modification; and in 1861 Broca published his remarkable discovery, indicating, on the basis of post-mortem examinations, that destruction of the third frontal convolution gave rise to aphasia.

In 1870 two remarkable series of investigations were published, which initiated a new epoch in our knowledge of the anatomy and physiology of the brain. The observations of Fritsch and Hitzig in Germany were the first to see the light; but the experiments of Ferrier, which appeared soon after, had been conducted without a knowledge of what the German investigators were doing. These two series of experiments were both of them set in motion by theoretical considerations; but I shall refer to only one of these, that of Dr. Hughlings Jackson, of London, who has always been the philosopher among physicians. He said to himself that there must be parts of the brain in which the "raw materials of consciousness," the ideas of color, form, sound, motion, and the like, must lie separate from one another. He further noted the fact that when epileptic attacks occurred it was common for the spasm to begin with contractions of a few muscles — those of the hand or face preëminently — and then to spread to the rest of the body in regular order, and offered the hypothesis that, corresponding to the order of succession in which the different parts became involved, there would be found a mosaic of centers in

the cortex of the brain. . . . Dr. Ferrier's investigations were begun in order to test this hypothesis.

It would be impossible for me to pass in detail over the wonderful series of experiments which have been made since that day, and I can only indicate their general character and general results.

In character they have consisted in stimulation of the surface and deeper lying portions of the brain by electricity and other means, and in the removal by excision, cauterization, a stream of water, etc., of different cortical areas. [Dr. Putnam pointed out on the models and diagrams taken from Ferrier, Horseley, and others, the position of the centers corresponding to the movements of the face, hand, arm, leg, trunk, etc., the area concerned in motor aphasia, the seat of vision, of hearing, etc.] If the fissure of Rolando is taken as a line of departure, running as it does across the convex surface of the brain, the motor areas may be found to lie immediately adjoining this fissure, while the occipital lobe is concerned mainly with vision, and the temporo-spheroidal lobe with hearing. The seat of the sensory functions of the skin occupies, probably, more than one place, since sensory impairment follows injury in the so-called motor area (which, by the way, is really an area for the sensation of motion performed), and also, in all probability, lesions of the so-called limbic lobe on the median surface of the brain. The so-called centers do not form a mosaic, but overlap, and the different layers of the cortex perhaps have different functions, sensory, motor, and the like; the cortex contains, also, centers for thermo-taxis and respiration, and, in short, for all the functions of the body. The anterior lobes of the brain do not seem to be much concerned in motion or sensation, and even when they are badly damaged, as happened in the celebrated "Crowbar Case," the patient may retain the ordinary functions of life. At the same time it is probable that, since this part of the brain increases in size as we ascend the animal scale, some of the most important mechanisms for the higher intellectual life reside in it.

[The next subject taken up was the practical clinical results of these discoveries, and the general character of the surgical operations for tumors, abscesses, and the like, was described. The theory that epilepsy may be due to a localized cerebral lesion, and therefore susceptible to cure by cortical excision, was discussed, but on the whole this theory was discarded, except for cases of definitely localized irritation.]

As to the question how the brain acts, we find ourselves forced to readopt, in some measure, the views of the older physiologists, though using them in a new sense. In other words, the essence of brain activity is in the arrangements that exist for the association of the functions of the different parts on an enormous scale, and the bulk of the brain is made up of associating tracts of nerve fibers, which lie packed together so closely that on cross section the surface appears as homogeneous as a piece of cheese. If we go down to the lowest vertebrate known, the *amphioxus*, or lancetfish, we find a brain that is scarcely larger than the spinal cord, of which it forms the extremity. Such an animal as this gets on about as well without his brain as with it, the spinal cord being sufficient for life and most of its functions. As we ascend in the scale, we find the functions of the brain becoming steadily more important, and the spinal cord taking a less and less independent place. Even the dog, however, will bear the loss of the hemispheres of the brain fairly well, if sufficient time is allowed him to gradually accustom himself to do without them [Goltz]. In the lower vertebrates the functions of vision and sight are rudimentary, and serve only to guide instinctive acts which result quickly in motion. In the higher animals these functions occupy a relatively enormous area, and are concerned in every thought of the mind, either directly or through symbols. We can perhaps study out the general mode of action of the brain the best by taking one example, the function of language.

When the child learns to speak, his first effort is usually to reproduce a sound which he hears, connecting it very early, though not necessarily at first, with the sight of an object or some more or less complicated idea. His next step is to apply his sound or word to a class of related objects or ideas, the word "bread," for example, being often used for different kinds of food; and then to discover that this expression has been outgrown, and that a differentiation is needed.

However far we trace this process we find the same factors at work, and however complicated language becomes, we test its degree of perfection by the richness of its individual symbols and the differentiation in meaning of which its symbols admit. I beg you now to note that the richness of meaning of a given symbol implies a corresponding coördination or focusing of a correspondingly great number of cerebral functions. Think, for example, what such a word

as "home" or "patriotism" is to the cultivated or fine person, compared to the rude or savage person; or take such a word as "justice," and consider what it means to the primitive man, who knows no one beyond his family or tribe toward whom he is called upon to show consideration, and what it means to the true philanthropist, who regards himself as akin to all the world. To this increased wealth of meaning of the word an increased coördination of cerebral processes corresponds. The necessity for the coördinated action of the various parts of the brain in speech is shown not only by the study of word symbols, but by studying the derangements of speech known as aphasia. [Dr. Putnam then pointed out on the model the way in which lesions of the motor speech area on the one hand, and the sensory and visual area on the other, and the tracts that unite them, may interfere with the speech function.] When we speak a sentence, that sentence rings in the inner ear (auditory cortical area) before it is uttered, and without this it cannot be spoken correctly. The different forms of aphasia occur to a slight degree among healthy persons, under the influence of fatigue, embarrassment, and the like. The fact that we are not conscious of all this intricate brain action which precedes some overt act or utterance does not show that it is not there. Consciousness has been described by one writer as like the little ripples that are seen on the surface of the sea, which strongly attract our attention, while we hardly recognize the existence of the great waves moving underneath.

Two general facts of recent discovery are of interest. One is that, in spite of these intricate arrangements for associated activity of the different parts of the brain, no two ganglion cells are actually united. The fibers grow out from each cell, forming long processes which terminate in the neighborhood of other cells, but do not actually enter into connection with them. So it would seem that the associated action of the different ganglion cells must take place by a process something like induction.

Another point of interest is that it has recently been discovered by Mr. Hodge, of Clark University, that when ganglion cells enter into activity demonstrable changes take place in them, leading to a rarefaction of the protoplasm and a condensation of the nucleus.

Finally, the conclusion may be insisted on strongly that a study of the evolution and functions of the brain leads us irresistibly to the conclusion that it is intended that in the "redistribution of

force for useful ends" all the activity of the brain should result in definite acts, just as much as the nervous arrangements which govern the action of the heart or the other viscera, and the brain should eventually give back all the force that it receives, as the cushion of the billiard table throws back the ball.

If a great deal of our cerebral activity seems to be a contrivance for luxury or idle pleasure, this is because we are not living up to our possibilities. The best educational developments of the present day are those that teach efficiency combined with the power of associating and focusing for a given end the largest possible number of associations and ideas.

A large class of nervous disorders to which modern society is prone are those which come with an undue development of the functions of perception and sensation over those of effective action. A man must not be a narrow-minded Philistine, on the one hand, but on the other, he must not be a sentimentalist. When efficiency is secured at the expense of broadmindedness, we have the narrow man, whose thought symbols are meager in their content. On the other hand, effective action is, after all, a higher function than simple appreciation. Thus the function of speech is a higher function than that of simply understanding, provided that the subject matter in both cases is the same; and so in the neurasthenic and hysteric brain we find a rank overgrowth of sensibilities which cannot be utilized in action, and to counteract the tendency toward this condition is one of the highest functions of education.

THE HOLLERITH ELECTRIC CENSUS SYSTEM.

By T. C. MARTIN, Editor of the "Electrical Engineer," New York.

Abstract of a paper read March 10, 1892.

It was long since evident that, with our rapidly growing population and the universal desire to see the returns as soon as possible, the old methods of compiling a census would not do. The appointment of the Superintendent of the Census was soon followed by the naming of a commission to advise him as to the methods to adopt of tabulating census data. To this commission three schemes of tabulation were presented. That submitted by Mr. W. C. Hunt proposed to transfer the details given on the census enumerators' schedules to cards, distinctions being made in part by the color of the ink, and in part by writing on them, the results being reached afterwards by hand sorting and counting. The next plan, that of Mr. C. F. Pidgin, contemplated the use of "chips," which should be duly sorted and counted. These "chips" were to be slips of paper of various colors, embracing data printed in different colors, so as to indicate the readings of the schedules. Last came the system of Dr. Herman Hollerith. In this plan the information given in the schedules was to be expressed upon cards by punching holes in them in certain positions. The tabulation from these cards was to be made by passing them through a press which would register their indications electrically on dials.

These three methods were put to the test, four enumeration districts of the census of 1880, in the city of St. Louis, being taken. It was found that the time occupied in transcribing their contents by the Hollerith method was 72 hours, 27 minutes; by the Hunt method, 144 hours, 25 minutes; by the Pidgin method, 110 hours, 56 minutes. The time occupied in tabulating was found to be as follows: By Hollerith's electrical counters, 5 hours, 28 minutes; by the Hunt slips, 55 hours, 22 minutes; by the Pidgin "chips," 44 hours, 41 minutes. The Commission estimated that on a basis of 65,000,000 pop-

ulation the saving with the Hollerith apparatus would nearly reach $600,000. As a matter of fact the saving is 40 per cent. more than was expected. It is needless to add that Mr. Hollerith's system was adopted.

Each of the broadsheet schedules of the eleventh census provided for some thirty details regarding any of ten individuals. Such a sheet would therefore serve for a family or household of ten people; but as a matter of fact it was found that the average fell slightly below five, so that in the neighborhood of 13,000,000 of these schedules were sent into the Census Office. The first thing to be done with these records was to get at their gross totals, and upon this work the Hollerith system was first put. The machine was fitted with a small numbered keyboard, the keys being connected electrically with the dials, which were so arranged that one of them would furnish the grand total of families as a check against the separate totals of the others for families of different sizes. The keys were in either two or three rows, of which the top one, stamped from 1 to 8, recorded the number of families in each house. The other two rows, nearer the manipulator, were numbered from 1 to 10 and 11 to 20, and recorded the persons in each family. The enumerators having given this information at the top of their schedules it was easy to transfer the items to the dials of the machine, or make special note of such rare families as exceeded twenty members. Evidently the multiplying of the number of families by the number of persons in each class would, if correct, yield the result indicated by the "total;" and hence the work was capable of very thorough check.

In this manner the first or "dwelling house" count of the whole population of the United States as it stood on June 1, 1890, was made. Practically only six weeks were needed for the task. The last returns were not received until November 10, but the official count of "62,622,250" was issued on December 12. Yet all the figures had been thoroughly checked; in reality, the people of the United States had been counted twice.

The next step was to transfer the particulars as to each individual of the 62,000,000 from these 13,000,000 schedules, and for this purpose Mr. Hollerith had devised the machine known as the "keyboard punch." It is about the size of a typewriter tray, having in front a perforated punch board of celluloid. Over this keyboard swings freely a sharp index finger, whose movement, after the manner of a panto-

graph, is repeated at the rear by a punch. The movement of the punch is limited between two guides, upon which are placed thin manilla cards $6\frac{5}{8}$ inches long by $3\frac{1}{4}$ high. The keyboard has twelve rows of twenty holes, and each hole has its distinctive lettering or number that corresponds to the inquiry and answer respecting each person. Hence, when the index finger is pressed down into any one of these holes the punch at the back responds by stamping out a hole in the manilla card. At first glance, perhaps, the keyboard looks complicated, but it is scientifically grouped and is very readily learned. For such inquiries as are answered by one of a very few possible classes — sex, for example — the answer is simply "male" or "female," or "M" and "F." Where, however, the answers would cover a wider range of classification, as in age, running from one to one hundred, recourse is had to a combination of two holes; the first indicating a group, as from twenty-five to twenty-nine years, while the second hole designates the detail single year in that group. That the work of punching became as easy as any other task requiring ordinary intelligence is shown in the fact that the estimated average of 500 cards per day per clerk resolved itself very soon into an actual average of 700. It is stated that some of the more expert punchers, working from 9 A.M. to 4 P.M., have done 1,100 cards, with an aggregate of 18,700 holes.

After the cards left the punching clerks they were kept in their enumeration districts, and they had to be further punched to show the exact locality they belonged to, *i.e.*, the civil division of which the enumeration district formed a part. For this purpose the space of about one inch across the left-hand end of the card was left blank, no portion to the left of a fictitious line being punched on the keyboard punch. This space is further divided by imaginary lines into forty-eight squares, in the combinations of which every enumeration district can be recorded, and it is perforated by means of the "gang punch." The combination for any given enumeration district is arranged in this, and then all the cards of that district are passed through. From three to six cards can be punched at a time (hence the name), and pressure can be applied by either the hand or the foot. When this is done the cards are complete.

The percentage of bad work was very small. Where the errors were "inconsistent," *e.g.*, where a child of ten would be registered as of no sex, the machine would sooner or later spot the mistake and

refuse to count the card. As to "consistent" errors, those, namely, in which a district messenger might be punched as a professional runner, it is safe to say that such errors were necessarily very few, if only for the reason that it is at least as easy to punch in the right hole as in the wrong one; and these errors would, moreover, on a mathematical basis, be less likely to occur in dealing with holes that are a quarter of an inch apart than where the same record was made under the old system on lines only one eighth of an inch apart on large tally sheets. But besides the natural checks on errors consistent and inconsistent, there was the further check of a frequent examination of the work, as it proceeded day by day and hour by hour.

The next step was to group and count the 1,000,000,000 facts contained by these cards, and this was done by the Hollerith machines. These consist of three main parts; namely, the press or circuit-closing device, the dials or counters, and the sorting boxes. The press consists of a hard rubber plate, provided with three hundred and sixteen holes or pockets, the relative positions of which correspond with those of the holes in the keyboard and "gang punches." Each of these pockets is partially filled with mercury, and they are thus in electrical connection when the circuit is closed. Above the hard rubber plate swings a reciprocating pin box, which is provided with a number of projecting spring-actuated points, so hung as to drop exactly into the center of the little mercury cups below. These pins are so connected that when a punched card is laid on the rubber plate against the guides or stops, and the box is brought down, all the pins that are stopped by the unpunched surface will be pressed back, while those that correspond with punched spaces pass through, close the circuit and count on the dials.

The front of each counter is three inches square. Each dial face is divided into one hundred parts, and two hands travel over the face, one counting units and the other hundreds. The train of clockwork is operated electrically by means of the electro-magnet, whose armature as it moves each time the circuit is closed carries the unit hand forward one division, while every complete revolution actuates a carrying device which causes the hundred hand to count. In this way each dial will register up to 10,000. A noteworthy feature of these ingenious little dials is that they can quickly be reset at zero, while they are also removable and interchangeable. The electrical connections are made simply by slipping them into the frames and clips in the upper part of the machine.

The third element in the system is the sorting box. The box is divided into numerous compartments, each of which is kept closed by a lid. The lid is held closed against the tension of the spring by a catch at the free end of the armature. If the circuit is closed by the press on the machine, through the electro-magnet, the armature is pulled down, releasing the trigger of the lid, which is at once thrown up by the spring, and remains open until put down by a slight touch of the operator's hand.

If, now, it is desired to know in a given enumeration district, or all of them, the number of males or females, white and colored, single, married, widowed, etc., the binding posts of the switch board corresponding with these data are connected with the binding posts of the dials on which these items are counted. If it is also desired to assort the cards according to age groups, for example, the binding posts of the switch board representing such groups are connected with the clips into which the sorting-box plug fits. The circuits being thus prepared, when a card is placed in position in the press, and the handle of the pin box is depressed by the operator so that the circuit is closed through the holes in the card, not only will the registration be effected on the counting dials, but the single sorting box that has been selected for a given age group is opened. The operator releases the handle of the pin box, removes the card deftly from the press, deposits it in the open compartment with the right hand, and pats the lid down again, at the same time bringing another card into position under the press with the left hand. It is done much more quickly than it is described. When all the cards in the tin case of any district have thus gone through the press, the record taken from the dials will show the number of males, females, white, colored, etc., while the cards will have been assorted into age groups.

But the Hollerith machine is capable of much more than this. In statistical work it is found that the most valuable information does not consist in these elementary items, but in facts that are more difficult to obtain, namely, combinations of these items. Thus it is interesting to know how many dwellers in this country are males, and how many females; also, how many are white and how many are colored. But it is at least as essential to know how many of the white males are native born or foreign born, and how many are the children of native born or foreign parents. Hence it is desirable to find means for counting, not simply the number of white males, but the number of

white males, native born, of native parents. Mr. Hollerith's machines do this as easily as they do the lighter work. The old familiar principle of the relay is brought into play very ingeniously by means of a special but simple form. These relays are mounted together in the racks at the bottom of the machine. It is simply a question of arranging the counting dials and the relays, or, if desired, the sorting boxes can be treated in the same way. When the machine is once connected up, the combination sought yields its results just as readily as though it were a single item. It is obvious, too, that multiple contact relays could be used, carrying the ability of the machine even further, if one wanted to do it in that fashion. Moreover, the machine is not confined to tallying one set of facts, but will take several at one and the same time, being limited only by the number of counting dials. The machine also lends itself to analytical work, not less than synthetical. In statistical investigation the analysis naturally becomes finer as the area enlarges, and here the sorting box is of great service. As has already been stated, the cards are primarily massed in enumerating districts. For such small areas the information required groups the population under comparatively few heads. In practice it is found that such classification can generally be counted on the forty dials that the machine embraces normally as a full equipment, and the arrangement is made accordingly. But while counting this classification the cards can also be assorted into groups that will form the basis of the analysis for the next larger group of territorial areas; so that if the cards are divided into twenty groups we shall have at the next handling of the cards a classification of 20×40, or 800 statistical heads. If at the next step we subdivide each one of these twenty groups into twenty more, the third handling of the cards will give us $20 \times 20 \times 40$, or no fewer than 16,000 statistical heads. Thus a few fine manipulations will give an extraordinarily fine degree of analysis, and the compilation will have a value from its minuteness that could be reached in no other way.

It is estimated that each of the machines thus compiles and registers information daily that would require the efforts of twenty clerks, if sought by the old system of tally sheets. But that is not all. Added to the ability to secure special details, finer analysis and the economy in time and labor, we have the greater accuracy. The machine automatically throws out any card that is wrong. Suppose,

for instance, that age or sex has not been punched. Where there should be a hole for the plunger pin to go through, closing the circuit, the card is intact. The circuit stays open, and the monitor bell just to the left of the press refuses to give its signal of correctness. It is then a very easy matter to refer back to the enumerator's schedule, and fill up the deficiency by the paradoxical process of making a hole. Suppose it be desired to connect up the machine so that only cards for New York should be counted. A missorted card belonging to Chicago would at once be rejected. The "gang punches" of the two cities not agreeing, the wrong cards would leave the circuit open. Moreover, the same indications are made, of course, by the same holes for all like data, so that one could run a wire straight through a mile of them. But this could evidently not be done with written cards, and the digging through the 150 tons of written cards for such as had gone astray would be a job preferably postponed until census clerks were clairvoyants.

It is evident that the probabilities of error in this wonderful counting apparatus in reality narrow themselves down to the punching; and, as has been pointed out, even then the only errors that escape detection are those in which the information given, while it may not furnish the exact fact, is still consistent with the other facts punched. Even these could be eliminated by comparison or check of every card, and it is surely hypercritical to complain of results so close to absolute accuracy. It is to be borne in mind, too, that a card wrongly punched involves only the possible miscounting of a single unit, whereas in all previous methods the counting up on sheets has involved miscount at each footing up of a column.

A HAND-TELESCOPE FOR STADIA-WORK.

By ROBERT H. RICHARDS, S.B.

Read March 24, 1892.

If one holds up a prism or wedge of glass with narrow angle, say 1° to 2°, and compares the transmitted image with the image seen above or below the prism, the former will be found to be thrown to one side by an amount varying with the angle of the wedge. Speaking of the two rays as the direct ray and the bent ray, we may say that when the bisecting plane of the prism is at right angles to the line of sight, the angle between the direct ray and the bent ray will be constant for any given prism.

If now we place a prism or wedge of glass in such a position that it half covers the objective of a telescope, we shall obtain, on looking through it, two images of every object seen — one image by the direct ray, which comes through the uncovered half of the objective; the other which comes through the prism, and is the image by the bent ray. The angle of divergence of these two rays will be constant and unalterable, whether the telescope is directed to a near object, with its eyepiece at increased distance from its objective, or upon a distant object, with eyepiece nearer to the objective. That is to say, if the "throw" or apparent dislocation of the image is one foot in one hundred feet, it will be two feet in two hundred, ten feet in a thousand, and so on.

The usual form of stadia telescope has at the focal point of the objective two spider lines, placed at a definite distance apart, and intended, let us say, to represent a throw of one foot in one hundred feet. But as the distance between lines remains the same, while the distance from the objective to the webs differs with every variation in the distance of observed objects, it follows that the angle between the lines of sight which these two spider lines define cannot be constant, but must vary with every increase or decrease of distance between the instrument and the object viewed.

If in Figure 1 we represent three positions of the spider lines by

W_1, W_2, W_3, and three objects corresponding to those positions by O_1, O_2, O_3, at near, medium, and distant positions, we see at a glance, from the figure, that there is no constant angle represented by the spider lines, and that the only way to graduate a rod for the practice of stadia measurement by this method is to determine values for one foot at a sufficient number of distances, and to provide the rod with a graded scale accordingly.

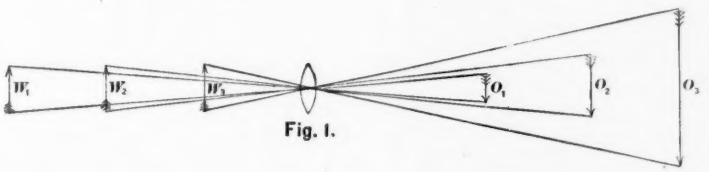


Fig. I.

The prismatic stadia telescope, on the other hand, has a constant angle for all distances and all focal lengths, and when the factor has once been obtained it may be used to graduate a rod with uniform scale from end to end.

Again, the usual stadia instrument involves two points of observation. The operator adjusts the lower spider line on the zero of the rod, and then observes the reading of the upper line on the rod. There are, therefore, two personal equations in the operation of taking readings. With the prismatic stadia telescope, on the other hand, both observations are made at once, just as the sailor, in taking the altitude of the sun at sea, brings the sun's image to the horizon and observes the contact. Only one personal equation is thus involved.

The spider-line stadia telescope cannot be used by simply holding it in the hand, but requires a firm support; for if it were used in the hand the first line would wander from the zero on the rod before the reading of the second line had been taken. The prismatic stadia telescope, on the contrary, can be used in the hand, just as a sextant is. Nevertheless, as the readings to be made with it are much finer than those of the sextant, a support will be preferred for most purposes.

The one great advantage of the spider line over the prismatic telescope is, that it uses the full light of the whole objective at all times, while the prismatic has only half light. This objection to the latter is completely removed when the spacing target rod is used; and it is fairly well met by the employment of self-reading rods, to which reference will be made later.

In adapting the prismatic stadia telescope to the needs of the surveyor, several important matters have to be determined relating to the prism, and also to the telescope and the rod.

In my experiments I have combined a telescope of 30 diameters magnifying power with a prism of 1 foot throw to 100 feet, and also with a prism of 1 foot throw to 150 feet. I shall speak of these two combinations, respectively, as 30 d : 100 and 30 d : 150. I have also combined a telescope of 20 diameters magnifying power with three prisms throwing, respectively, 1 foot in 50 feet, 1 foot in 100 feet, and 1 foot in 150 feet; and I shall speak of these combinations as 20 d : 50; 20 d : 100; and 20 d : 150. Finally, I have combined a telescope of 10 diameters magnifying power with prisms of 1 foot to 50 and 1 foot to 100; and I shall call these combinations 10 d : 50 and 10 d : 100.

The first fact I encountered in these experiments was, that 10 d : 50 and 10 d : 100 can be used with uncorrected prisms, since the amount of color does not seriously injure the observation; while no prism not thoroughly achromatic was found satisfactory for either the 20 d or the 30 d telescope.

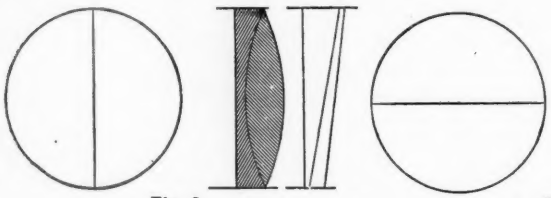


Fig. 2.

Fig. 3.

Figure 2 represents what appears to me to be the rational and proper mode of combining the prism and the objective; while Figure 3 shows an improper combination. In Figure 2 the bent rays are the exact counterpart of the direct rays, while in the adjustment of Figure 3 this is not the case.

Choice of a Prism. — For hand use a wide prism is preferred, say 1 foot displacement in 50 feet distance. For a fixed telescope 1 : 100 or 1 : 150 would be preferred, according to the distances to be sighted and the length of the rod to be used. A prism throwing 1 : 150 will permit readings at 1,500 feet on an 11-foot rod, while a 1 : 100 prism will read only to 1,000 feet on the same rod. On the other hand, where a standard steel tape with sliding targets is

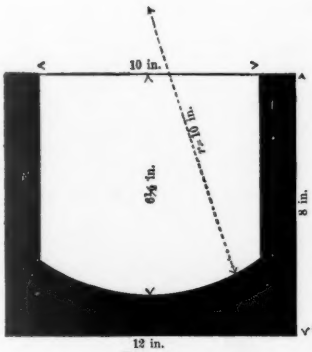


Fig. 4.

Fig. 5.

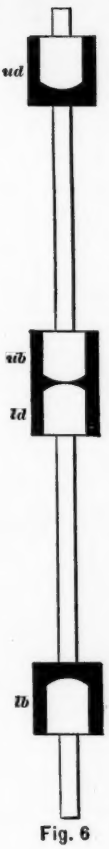


Fig. 6

used instead of a rod, we may say that the wider angle prism will give more accurate work than the narrower.

Choice of a Telescope.— Since a large field is not needed, we have to deal with two considerations only: the lightness of the instrument and its power. If the former consideration governs the choice, I would recommend a light 10 *d* or a light 20 *d* telescope; if the latter, I would recommend a 20 *d* or a 30 *d* telescope.

Choice of Rods. — In this direction I believe I have settled the question as regards the choice of a spacing rod with sliding targets; but I do not feel so sure with respect to the self-reading rods.

The spacing rod represented in Figures 4 to 9 is so preëminently superior to every other which I have tried that I strongly recommend it. This target stands out strong and bright under any circumstances. It can be read against a dark background in the woods, and also against a light sky background on a hilltop.

In Figure 5 the rod is represented as seen by the eye. Figure 6 shows it as seen by the prismatic stadia telescope. In this figure *ud*, *ld* are the upper and lower images by the direct ray, and *ub*, *lb* are the upper and lower images by the bent ray. The observer, of course, neglects *ud* and *lb*, and uses for his contact *ub* and *ld*. The important advantages of this form of contact are shown in the subsequent figures.

Figure 7 represents the targets approaching contact. Figure 9 shows the images lapping, in which case there is a bright, lens-shaped image, indicating the amount of lap. Upon its appearance the assistant is signaled to draw the targets slowly apart; and the instant the white lens becomes invisible the reading, Figure 8, is taken. The disappearance of this white lens gives a close and positive reading. The results stated below were obtained with this reading.

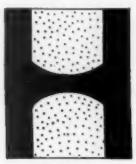


Fig. 7.

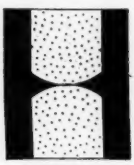


Fig. 8.

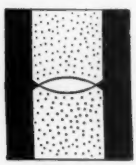


Fig. 9.

A target of the size shown in Figure 4 can be read easily at 2,000 feet distance with a 20 *d* telescope, in an even atmosphere. A much smaller target will suffice for short sights. The design of Figure 4 has more strong points in its favor than any other yet tried by me.

The spacing targets, Figures 4 to 9, may be used on a steel tape if the following conditions are observed: The tape must be held at right angles to the line of sight. If the right angle is at one of the targets, it will be found easier to reproduce than at a point half way between the targets. For distances much greater than 2,000 feet a larger target or a higher power telescope, or both, will be needed.

Figure 10 represents a tape as used by me on a 1,970-foot sight with the above targets and a 20 *d* telescope.

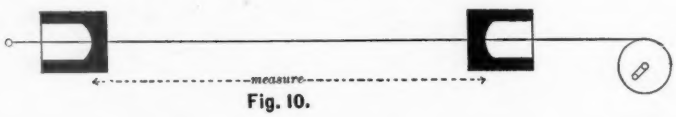


Fig. 10.

Self-reading Targets. — Three forms which have been experimented upon are represented in Figures 11, 12 and 13.

Figure 11 gives good results with a 10 *d* : 50 combination for short distances. It may be graduated, as shown, with 2-foot unit or with 5-foot or 10-foot unit. In the latter case, it would be used for long distances with a 20 *d* : 100 combination up to 30 *d* : 150 combination; but the individual feet would have to be divided by the eye. The skeleton second image on it reads 68 feet.

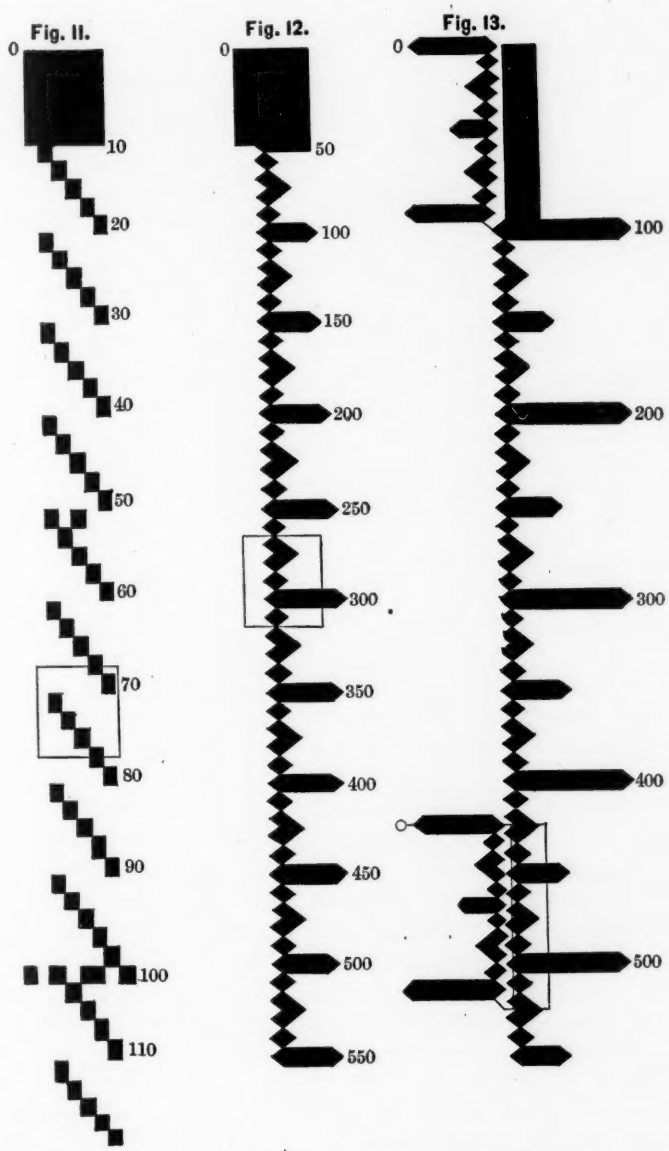


Figure 12 may be graduated with 1-foot, 2-foot, 5-foot, or 10-foot units, according as a short-distance or a long-distance rod is wanted. The skeleton reading of the second image upon it indicates 265 feet.

Possibly, for certain distances, this graduation may be found easier to read than that of Figure 11.

Figure 13 represents a target rod with an optical vernier. The space from 0 to 100 feet on the rod is graduated into eleven parts, while the spaces from 100 to 200, also from 200 to 300, and so on down, are graduated into ten parts. Moreover, the space from 0 to 100, which we may call the vernier, is graduated on the opposite side to the other readings, so that the second image can bring it down and give a vernier reading between the two images. The partial skeleton second image gives a reading of 423 feet, no dividing by the eye being required. By this system an 11-foot rod may be made for a 30 d : 100 combination, which will actually give readings of individual feet at 1,000 feet distance.

The vernier reading is the most fascinating idea I have met in my investigations. Whether it is really practical can only be decided in the field. The images which are important for the reading are half light images, and therefore dim, while with the other two forms of target a full light reading is obtained.

Limits of Error. — Partly by reason of the limited time at my command for experiments, and partly because every time I went out to get definite records of practice I made some discovery which led to an improvement in the apparatus, I can only promise at this time to give detailed figures at an early day as a supplement to this paper. The figures I am now prepared to publish were taken with a curved spacing target of the design shown in Figures 4 to 9.

With a 20 d : 150 combination, holding the rod at 100 feet distance, I obtained five separate readings of the distance in feet between the targets, which were 0.653, 0.654, 0.653, 0.653, 0.653. With a 30 d : 150 combination I made these four successive readings at 100 feet distance: 0.675, 0.675, 0.675, 0.675; all with the spacing target described in Figures 4 to 9.

If I had made an error of 0.001 foot upon the rod, this would correspond to an error of 0.15 per cent., or 0.15 foot in 100 feet. But I did not make this error in four readings with 30 d : 150, and only made it once in five successive readings by the 20 d : 150 combination. If the prism had been a 1 : 100 prism, the error referred to would have been 0.1 foot in 100. If the prism had been a 1 : 50, the error would have been .05 foot in 100 feet. I cannot imagine a reason why the percentage error at 1,000 feet or 2,000 feet, when

the atmosphere is steady, should be any greater than it is at 100 feet. From the above considerations, I believe I am safe in saying that the error of the prismatic stadia is well inside of 0.1 per cent.

I hope to present, in the near future, some figures actually obtained for both short and long distances.

If one desires to determine the distance to a point without the trouble of sending an assistant there, it may be done with a pair of Wollaston camera lucidas, as shown in Figure 14, in which W_1, W_2 are the two cameras.

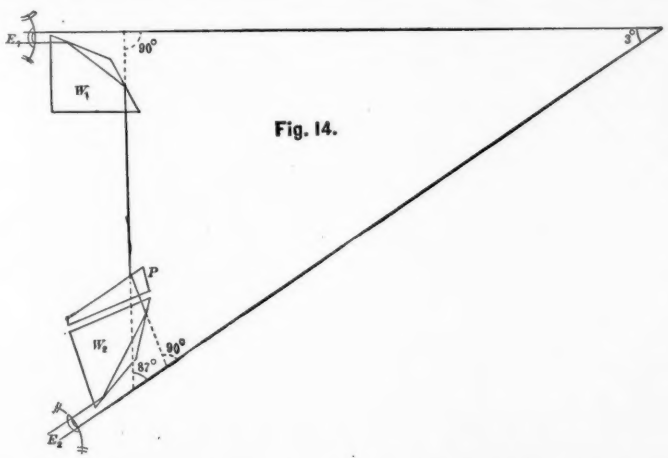


Fig. 14.

If the Wollastons both give 90°, then the requisite deviation from 90° may be obtained by inserting a prism, P, as shown. If, however, the two Wollaston angles add up to say 177° to 178°, then the apex angle will be 2° or 3°, and will answer without the addition of another prism. After the two observers, E_1, E_2, have found their places, so that their respective images coincide, then they can measure the base line between them by a prismatic stadia telescope; and knowing the factor of the Wollastons, 3 feet or 4 feet to 100, the distance to the unknown point may be determined approximately by multiplying the observed distance between E_1 and E_2 by the factor — 3 feet to 100, 30 feet to 1,000, 300 feet to 10,000, and so on.

In making my designs and in testing my instruments I have been helped materially by Captain A. H. Russell and Messrs. J. Hays Gardiner, W. H. Weston, Franklin Knight, Luis T. Verges and W. S. Hutchinson, friends to whom I wish to make acknowledgment.

MAGNETIC CONCENTRATION OF IRON ORE.

By HARVEY S. CHASE, S.B.

Read March 24, 1892.

THERE are in the records of the Patent Office drawings and descriptions of separating machines, whose letters patent have now expired, but which many years ago were fitted with permanent magnets or battery-driven electro-magnets, and did excellent work, as models, upon magnetic iron sands or clean magnetic ores. It is only within the past three years, however, that magnetic concentration has been practically established, and separating plants built which handle very large amounts of crude, low grade ore. Of such plants, fitted to handle from one hundred to one thousand tons of ore daily, there are now many; but before describing them it will be worth while to consider upon what material magnetic concentration must work, and then to examine the locations of the magnetite bearing strata, and the present market for concentrates made from such ores.

Magnetic oxide of iron, Fe_3O_4, occurs in nature in black crystals, which are naturally magnetic, and which vary greatly in size and are associated with widely differing minerals. These associated minerals in any ore form the so-called "gangue," and upon its constitution, as well as upon the size of the crystals of magnetite, depends the success of magnetic separation or concentration.

The problem of separation, as defined today, consists in handling quickly and cheaply large amounts of low grade ores, delivering this material (from which the best grade is often "cobbed," or picked by hand) to large jaw crushers; then to crushing rolls or pulverizing mills, which break it to uniform sizes, after careful screening and recrushing of the particles refused by the screens. From two to six or more passes are commonly required to gradually granulate the ore to the fineness desired, which is determined by the relative sizes of the magnetite crystals and those of the constituents of the gangue. The sizing commonly made in practice runs not finer than twenty "mesh,"

although in special cases reaching even fifty "mesh," or a condition much like coarse flour. This degree of fineness is, however, extreme; and while excellent concentrates of this minuteness have been made and sold, and used successfully in blast furnaces, yet it is very doubtful if there can ever be proper pecuniary return for concentrates made from material which requires such excessive grinding.

Between four and sixteen "mesh" is found the usual limit of granulation for nearly all ores from which concentrates can be made profitably today.

The Appalachian mountain system, composed in considerable part of the crystalline Archæan rocks which were the first to raise their heads above the great primeval ocean, contains throughout its length great veins or leads of the black oxide or magnetic oxide of iron, running mainly along the eastern slopes from the north side of the Great Lakes in Canada, through eastern New York, along Lake Champlain, and inward among the Adirondacks (famous for their magnetic ore, from which charcoal blooms are still made for horseshoe nails and other specialties, whose quality has never been rivaled); then crossing the southeastern portion of New York, through northeastern New Jersey, southeastern Pennsylvania, through Maryland, along the upper reaches of the Shenandoah and the James, and the Holston in Virginia, down into eastern Tennessee, western North Carolina, and northern Georgia. In many portions of this great stretch of a thousand miles this ore has been found in large quantities and of great purity, but throughout the far larger portion of the distance the oxide is so disseminated through the rocks that the percentage of metallic iron is too low to allow of its use in modern blast furnaces, so long as high grade Lake Superior or other hematites can be obtained even at thrice the cost per ton.

Along this line are planted the anthracite and charcoal furnaces, which before the advent of Bessemer were accustomed to use the ordinary ores, making ordinary foundry and forge irons. Today many of these furnaces are closed, and many others are running with little or no margin of profit, on account of the competition of modern, well-equipped furnaces located near the finest coke or near the magnificent hematites of the Lake Superior districts. The cost of transportation is heavily against these old eastern furnaces, inasmuch as not only coke but ore, has now to be brought across the mountains, distances of from 300 to 1,000 miles; so that, in spite of the nearness of the

great markets for pig iron and the relatively short haul to the seaboard, the district east of the Alleghenies has shown for many years that apparently its day for profitably making pig iron is past. But now magnetic concentration has stepped to the front, and after long and very costly experimentation during the past ten years, is prepared to furnish to these eastern furnaces an ore which is excellent for blast furnace use, and is especially well fitted for the needs of the direct process steel-maker, and which is easily and very cheaply produced from waste dumps and from mines long ago abandoned (because of the low percentage of iron, or high phosphorus, or sulphur, or other deleterious ingredients), and situated oftentimes within a few miles of the furnaces.

For instance, there is in New Jersey a mine, belonging to a well-known iron company, which has been worked steadily for very many years, shipping 60 per cent. of the amount mined as ore, which runs about 55 per cent. of metallic iron, while the remaining 40 per cent. of the output, containing from 35 to 40 per cent. of metallic iron, has been thrown upon the waste dump or stored in the worked-out rooms in the mine. It is now found that this refuse is exceedingly well adapted for concentration, and that by establishing a plant which will cost not over thirty-five thousand dollars, an output of about 100 tons of concentrates per day, running 65 per cent. of iron and low in phosphorus, will be obtained, and the resulting profit from the sale or use of these concentrates is sufficient to much more than return the cost of the plant each year; or, to put it differently, to pay a dividend of 4 per cent. and over upon the total capital stock of the company, and all from what has long been considered worthless refuse.

There are many mines in New Jersey, New York, and Pennsylvania which are today in just this condition, and which have been waiting the appearance of a practical, cheap, and durable magnetic separator, which can be set up and run day and night, if need be, without special electrical attendance, and the repairs to which can be confined to the smallest proportions, and made quickly by common, unskilled labor.

The problem of magnetic separation of iron ores as found practically in the mines is a very different one from the separation of a purely magnetic substance from a purely non-magnetic one, because the crystals of magnetite scattered through the ore-bearing rock are

of very different sizes. The average may be a certain definite size, and the crushing and screens adapted thereto; but there will be a large percentage of very fine crystals which, in the crushing for the average, will not be broken apart from the gangue, and if separated into "heads" will carry gangue with them, and if separated into "tails" will carry too much iron into the "tails," and cause loss. There are two ways of solving the problem, one of which is to crush all the material to the size of the finest particles; which means, of course, a large crushing plant, heavy wear and tear and excessive cost, sufficient often to prohibit the process. This is the common method of treatment, however, and many thousands of dollars have been expended upon separators and upon crushing machinery as thus applied. The more modern method is to crush coarsely at first, and separate upon a machine which has a power of selection, so that there will be first thrown off a "tails" containing practically no magnetite; next a second "tails," or middlings, with some iron in the mixed particles; next a third, and fourth, or other division, and finally a practically pure magnetite as "heads." The first "tails" are thrown away, the "heads" are sent to the bins or cars, and the second and third or other "tails" are treated again, and such portions of them as may be necessary crushed sufficiently fine to break apart mechanically the magnetite from the gangue. The crushing of three fourths of the product is thus saved, and the cost and wear and tear correspondingly reduced, and the problem is efficiently and economically solved.

The machine shown is one intended for this purpose, and as it is of my own design I prefer to let it speak for itself, and to test it with various kinds and sizes of crushed ores.

The machine consists, first, of a spirally wound magnetic wheel, giving a very strong magnetic field, about its whole circumferential area, and owing to the method of winding it is equally efficient whatever its length, though the regular sizes of machine vary by one-foot divisions, and determine the width and capacity of the separator.

The crushed ore is fed upon the top of this wheel by a patent feed, and is carried by a belt of cotton duck around through the magnetic field downwards. The absolutely non-magnetic particles are thrown off at once by centrifugal action, while all particles wholly or partially composed of magnetite are carried to the under side of the wheel, from which the belt passes nearly horizontally under a

peculiarly made magnet with "consequent poles" of varying strength and distance from the belt, causing a rotative and tumbling action in all these particles as they pass through successive magnetic fields, while held up close to the belt by the magnetic attraction, directly against the influence of gravity. The coarser mixed particles fall out first, then the finer, and finally the "fines" or "slimes," and are caught in separate receptacles.

The pure, or nearly pure, magnetite traverses the whole length of the under side of the belt, usually from three to four feet, and at the end is attracted by a magnetic wheel, similar to the first one and four inches in diameter, around which the belt takes a quarter turn upward for twelve inches, and then passes over a first pulley and under a second, and returns horizontally above the magnets to the first wheel. By the attraction of this second magnetic wheel the magnetite particles are whisked around the corner, while the fine dust continues in a tangential line horizontally. At this point a current of air strikes the belt and assists to drive off this dust, or in the wet process a current of water acts in the same way. The magnetite, now going upward, passes out of the field of the second magnetic wheel, and is immediately drawn off from this belt by a third magnetic wheel, over which runs a second belt to a pulley at any desired distance. The concentrates are thus loaded on this second belt and conveyed to any point desired and dropped into bins or cars, the intermediate products being treated again as described before. The wet process machine varies from the dry only by a water-tight tank, in which all the moving parts are set beneath the surface of the water, the "tails" and intermediate products being taken out from the bottom of this tank by ordinary wooden scrapers at an angle, while the "heads" go off upon the second belt out and above the surface.

Certain ores work much better wet, and others dry; and this separator has a marked advantage, as by drawing off the water from the tank the wet machine becomes at once a dry machine, and works equally well as such.

More rapid work can be done dry, but much cleaner and more perfect work, wet; and the repairs and renewals are much less in the wet process, as the water acts as a lubricator as well as a cleansing medium.

The machine shown was about five feet in height and four feet by three in floor space, fitted with motor, rheostat, am-meter, fuses,

switches, etc., complete in itself, so that only the wires of a hundred and ten volt circuit had to be connected. Tests were made upon Lake Champlain magnetic sands, upon Witherbees, Sherman and Company's high phosphorus and low phosphorus ores, upon waste from the dump of the Hibernia mines, New Jersey, and from the Weldon mines (a very coarse ore) in the same State. The products were collected in separate boxes, and tested by the members present with strong horseshoe magnets. In every case the "tails" showed no appreciable iron, scarcely a tenth of one per cent., while the "heads" ran above 68 per cent. of iron. The other products included the "fines," which carried a trifle of iron in minute division, while the mixed particles showed upon examination that recrushing was essential to break the fine-grained magnetite from the coarser gangue.

A DESCRIPTION OF SOME REPEATED STRESS EXPERIMENTS.

By JEROME SONDERICKER, C.E.

Read April 14, 1892.

A LARGE proportion of the fractures occurring in the ordinary use of structures and machinery is the result of repeated stresses. For the determination of the capacity of material to resist such stresses the ordinary tests of strength are inadequate. Wöhler's noted experiments brought this matter prominently before the engineering profession, and his law is now quite generally recognized. This law is as follows: "The fracture of material can be effected by variations of stress repeated a great number of times, of which none reaches the breaking limit. The differences of the stresses which limit the variations of stress determine the breaking strength. The absolute magnitude of the limiting stresses is only so far of influence as, with an increasing stress, the differences which bring about fracture grow less."

In order to use to the best advantage in design the results of repeated stress experiments, it is important to understand the causes which lead to fracture in structures under such stresses. Aside from the influence of the quality of the material, two explanations suggest themselves: First, that fracture results from molecular changes produced by the repeated stress, extending through the entire mass, and altering the physical properties of the material in such a manner that it becomes less and less capable of supporting its load; second, that the fracture is the outcome of a gradually extending crack; such cracks starting at weak places in the material, such as flaws, surface indentations, and the like; or at places where excessive stress is caused by more or less abrupt change of form, as at shoulders, keyways, angles, etc. In brief, we conceive the cause of failure to be local, the material as a whole suffering no deterioration.

In investigating the cause of failure under repeated stresses, it is important to make a study of the elastic changes produced by such

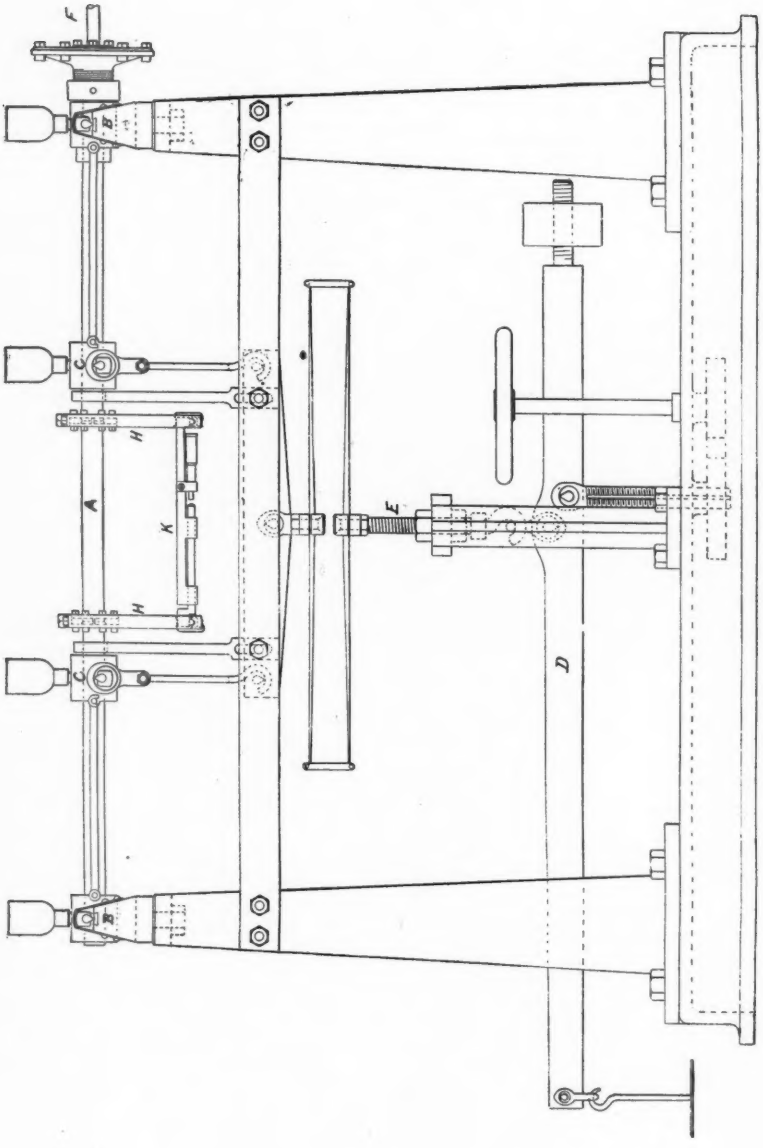
stresses. We have as yet very little information in this direction. The most noteworthy experiments are those of Bauschinger, published in *Mittheilung* xv, 1886. These experiments were performed on bars subjected to repeated tension stresses. In addition to these we have a series of experiments on rotating bars, made at the Watertown Arsenal, and published in the United States Government *Reports of Tests of Metals made at Watertown Arsenal,* for 1888 and 1889.

About one and one half years ago the writer began a series of experiments at the Institute for the purpose of making a special study of the effect of repeated stresses upon the elasticity of iron and steel; and although at present the tests are only fairly begun, it is the purpose of this paper to present the results thus far reached. The tests were made upon bars loaded transversely while rotating as a shaft; thus the material was subjected to alternate tension and compression stresses of equal magnitude.

The machine used in making these tests is shown in the figure on the next page.

The test shaft A is supported at B, B, and loaded equally at the two points C, C, which are equidistant from the supports. The load is applied by means of the lever D, acting through the spring, cross-bar and links shown in the drawing. While the bar is rotating the rod E is clamped to the standard, the spring maintaining the load on the specimen; thus any variation of stress due to the vibration of the lever is avoided. From the manner of loading, the portion of the shaft between the points C, C is subjected to a uniform bending moment; and hence the shaft, if of uniform diameter, is equally stressed at all sections between these points and curves in the arc of a circle. One end of the test shaft is connected by a flexible coupling F with the driving shaft. The power is furnished by an electric motor, running day and night. The speed of the test shaft in all the tests thus far made was about five hundred revolutions per minute. An automatic device is employed for stopping the motor when the shaft cracks, but before it has broken completely in two. The halves are afterwards pulled apart in the tension machine, in order to examine the fractures.

The apparatus for measuring the elasticity of the test bars is as follows: Two arms H, H are clamped to the central portion of the shaft, at right angles to its length and 10 inches apart. A measuring apparatus K, consisting of a micrometer fixed to one of two



MACHINE FOR REPEATED BENDING TESTS ON ROTATING BARS.

sliding bars, is supported by these arms at points 5 inches from the axis of the shaft, spherical bearings being used. When the shaft deflects, the arms, pointing downwards, spread; the measurement taken being the distance that the two points 5 inches from the axis of the shaft move apart. These distances are for brevity referred to as deflections. The measurements were taken to $\frac{1}{10,000}$ inch, this corresponding to a deflection in the 10-inch length of about $\frac{1}{40,000}$ inch, and to an extreme fiber strain of about $\frac{1}{1,000,000}$. The arms remain attached to the shaft, revolving with it.

During the tests the machine is stopped at intervals of from one to four days, and a set of measurements taken, in order to determine what elastic changes have occurred. The quantities observed are total deflection, elastic deflection and set; the set being the deflection remaining after the load is removed, and the elastic deflection the difference between the total deflection and set. The order of procedure to be adopted in making the deflection measurements is a matter of the first importance. The minute sets occurring within and in the immediate vicinity of the elastic limit conduct themselves as if they constituted a sort of backlash or lost motion between the particles of the body; so, in order to obtain comparable results, we must follow a certain order in taking the observations, and adhere strictly to this throughout. Thus, if the machine be stopped with the measuring arms pointing downwards, then the load be removed, after which a series of observations is taken, first applying the load again to obtain the total deflection, then removing it to obtain the elastic deflection, the difference being the set, it will be found that this difference is nearly or quite zero; the re-application of the load causing no further permanent deflection. If, on the other hand, the shaft be stopped with the arms pointing upwards, then the load be removed and a similar set of observations taken after rotating the shaft 180°, a decided set will be obtained. This, moreover, will be twice what would have been obtained if the load had been removed while the shaft was rotating. In all the experiments the order of observations was as follows: (1) Stop the shaft with the measuring arms pointing upwards; (2) remove the load, then rotate the shaft 180°; (3) insert the measuring apparatus and take a reading; (4) apply the load and take a second reading; (5) remove the load and take a third reading. The difference between the first and second readings is the total deflection; between the second and

third readings, the elastic deflection; between the first and third readings, the set. The separate observations were taken at three-minute intervals, and were corrected for change of temperature in the test bar. This correction rarely amounted to more than one or two ten thousandths of an inch.

Thus far sixteen specimens have been tested, including wrought iron, open-hearth and Bessemer steel, and cold rolled shafting. The duration of the individual tests varied from fifteen hours to two months, the corresponding number of revolutions being about one half million and forty millions. The test bars are one inch in diameter, the cold rolled samples being tested in the condition in which they were received; the others were turned and polished. Some of these latter were of uniform diameter, the central portion of others being slightly reduced in section. All the bars of each set were of the same quality, in most cases being cut from one rod. The table on pages 79 and 80 gives a summary of the tests. Elastic changes occurred in the wrought-iron bars, and in the steel bars of sets 4 and 5. The changes were the same in character for all the bars of any one material, but differed for the different materials. The elastic deflections remained very nearly constant in all the tests, the changes occurring mainly in the set. The diagrams on page 78 represent these changes. The abrupt changes in the diagrams are due to changing the load on the shaft. The numbers on the diagrams indicate the fiber stress in pounds per square inch under which the shaft was rotating, as will be seen by reference to the table. The horizontal lines marked O are the lines from which the sets are laid off as ordinates. Each vertical space represents .001 inch micrometer reading, the corresponding deflection being about one fourth of this, as previously stated.

In the wrought-iron shaft, Diagram 1, the set under a stress of 24,000 pounds per square inch at first increased rapidly for a short time; after which it decreased, rapidly at first, then more and more slowly; the final set being less than one half that observed at first. When the stress was increased successively to 25,000 and then 26,000 pounds, no further changes of consequence occurred; but under a stress of 27,000 pounds changes occurred similar in nature to those observed at first, the final set under a stress of 27,000 pounds being less than the original set at 24,000 pounds. When a stress of 28,000 pounds was applied the shaft quickly broke.

The changes in the bar of soft steel, Diagram 2, are very similar in nature to those just described. The initial increase in set is wanting, the change consisting in a decrease of set, rapid at first, proceeding more and more slowly, and practically ceasing after about five million revolutions. The final set under 36,000 pounds is considerably less than the initial set at 32,000 pounds. The original elastic limit of the steel was 28,000 pounds per square inch.

In Diagram 3 we have represented changes exactly opposite in nature to those already described. Changes first occurred at a stress of 34,000 pounds, the elastic limit of the steel being 50,000 pounds. The change consists in a continuous increase of set, rapid at first, proceeding more and more slowly, finally ceasing. When the stress is increased successively to 36,000 pounds and 38,000 pounds, the resulting changes are similar, but more marked, the final set being .0118 inches, or over 4 per cent. of the total deflection. This shaft is still under test, and has already withstood a total of about nine million revolutions under this large set.

With a different form of diagram in each case, we may expect that other varieties of iron and steel might give still different diagrams, so only a partial discussion of them will be attempted.

1. In each case the changes are rapid at first, but proceed more and more slowly until the bar finally settles into a stable elastic condition. We conclude that elastic changes once begun do not continue indefinitely, and hence that it cannot be inferred that such changes will necessarily finally result in fracture.

2. In Diagrams 1 and 2 the changes were first apparent at the elastic limit of the material; and, with the exception of the initial increase of set in Diagram 1, these two diagrams represent the same general law of change; namely, a continuous decrease in the amount of set, rapid at first, proceeding more and more slowly, and finally ceasing. This continuous decrease of set harmonizes with the well-known effect of cold working of ductile metals, which is to diminish their plasticity and raise their elastic limit and breaking strength. Thus it would seem probable that in these two cases the diagrams represent the normal effect of the cold working beyond the elastic limit to which the bars were subjected.

3. The third diagram is so different from the first and second that we are led to believe that the changes produced in this steel by the repeated stress are of a different nature from those produced in

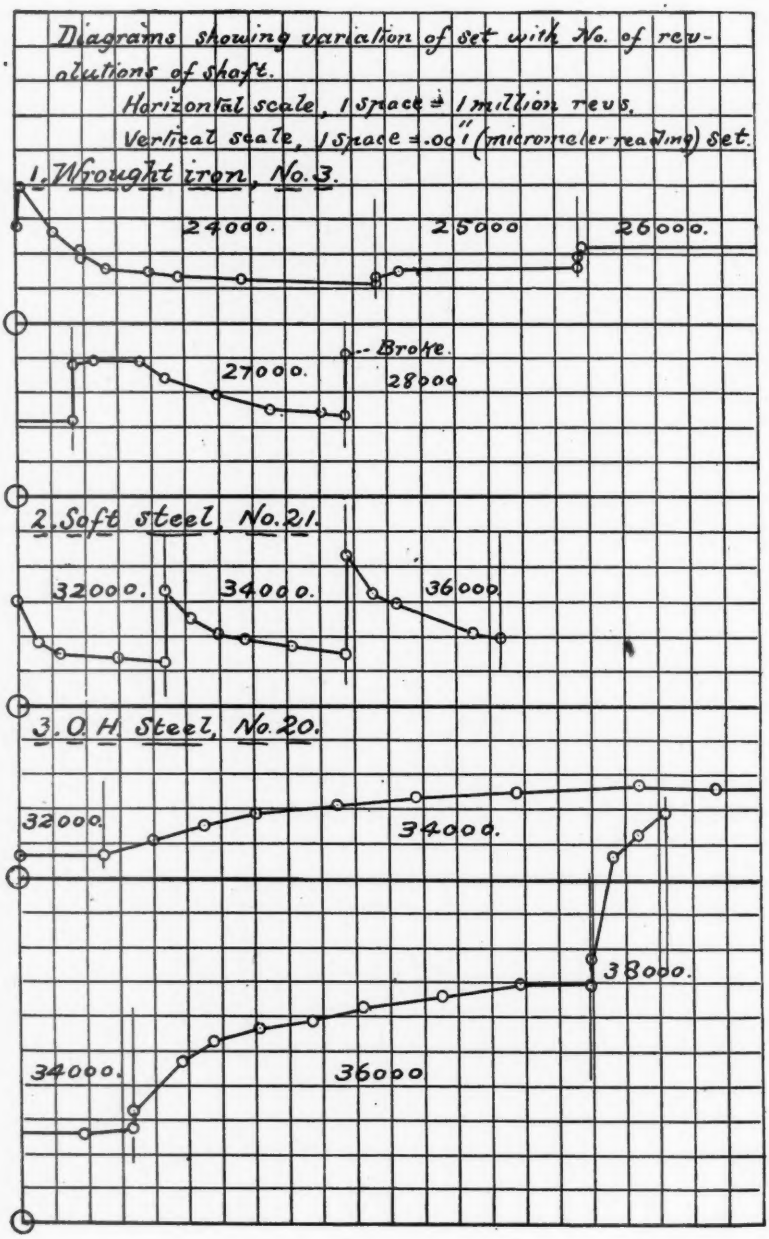
the other two cases. These changes occurred within the elastic limit, and the direction of the change is the reverse of the other two. The open-hearth steel had originally an elastic limit of 50,000 pounds per square inch. Considerable elastic change, however, occurred at a stress of 34,000 pounds, the set increasing from .0007 inches to .0028 inches; and under a stress of 38,000 pounds a set of .0118 inches, or over 4 per cent. of the total deflection, was reached. The soft steel had originally an elastic limit of 28,000 pounds per square inch. At the end of the test this steel had a set of .0019 inches as contrasted with .0070 inches in the open-hearth steel under the same stress; and it was at the end of the test more nearly perfectly elastic at 36,000 pounds than the open-hearth steel at 34,000 pounds. Whatever be the explanation of these opposite results effected in these two cases by the repeated stress, Diagram 3 proves conclusively that elastic changes may occur at stresses within the elastic limit.

4. The elastic limit does not appear to be a sufficient criterion for judging of the capacity of material to resist repeated stress. We have seen that in two cases the metal has successfully withstood stresses extending beyond the elastic limit; in the third, elastic changes tending to increase the set have occurred far within this point, and a large proportion of the test bars broke within the elastic limit without any elastic changes occurring.

5. In these tests, since the stress was uniform over a length of about twelve inches, favorable opportunity offered for observing the influence of local conditions in causing fracture. Of the fourteen bars thus far broken, two broke at little loose splinters on the surface, two at slight indentations caused by careless handling, three broke where the measuring arms were attached, two at one of the shoulders, and one at a mark burned around the shaft by the electric current; thus only four broke without any local cause being apparent. In the turned steel bars, when a cylindrical form was used, the shafts broke where the measuring arms were attached. In order to prevent this the central portion of the bar between the arms was slightly reduced in section, using carefully rounded shoulders; then fracture occurred at the shoulders. It is thus seen that the fracture can, in ten out of the fourteen bars broken, be assigned to local conditions. Again, it is improbable that changes of structure would occur without accompanying elastic changes; so we can confidently conclude that no change of structure occurred in the eight bars

which broke without elastic changes being produced by the repeated stress, and that in all these cases the fracture was the result of local conditions. It thus appears from these experiments that, in the majority of cases at least, fracture under repeated stress is not due to physical changes affecting the whole mass of the metal, but rather to such local conditions as were referred to at the beginning of this paper.

In conclusion, while no direct connection between the minute elastic changes treated in this paper and the resistance of the material to repeated stress has yet been established, it is evident that observation of these changes may be of assistance in discussing the results of repeated stress experiments; and the writer would urge the importance of making such observations in connection with experiments of this nature.


Diagrams showing variation of set with No. of revolutions of shaft.
Horizontal scale, 1 space = 1 million revs.
Vertical scale, 1 space = .001" (micrometer reading) set.
1. Wrought iron, No. 3.
24000.
25000
26000.
27000.
Broke.
28000
2. Soft steel, No. 21.
32000.
34000.
36000
3. O. H. Steel, No. 20.
32000.
34000.
38000.
34000.
36000

SUMMARY OF REPEATED STRESS TESTS.

1. WROUGHT IRON.

Elastic limit = 24,000 pounds per square inch. Tensile strength = 51,000 pounds per square inch. Elongation = 26% in 10 inches.

No. of Specimen.	Stress Lbs. per sq. inch.	No. of Revolutions.	Elastic Change.	Remarks.
1	15,000	5,220,000	No.	
. . .	26,000	2,285,000	Yes.	Broke 3½″ from center.
2	20,000	5,402,000	No.	
. . .	32,000	486,000	Yes.	Broke at center, at mark made by electric current.
3	24,000	10,727,000	Yes.	
. . .	25,000	8,962,000	No.	
. . .	26,000	3,931,000	No.	
. . .	27,000	8,155,000	Yes.	
. . .	28,000	589,000	Yes.	Broke at shoulder.
4	28,000	2,506,000	Yes.	Broke 1″ from center.

2. COLD ROLLED STEEL SHAFTING.

Elastic limit = 58,700 pounds per square inch. Tensile strength = 81,700 pounds per square inch. Elongation = 9½ % in 6 inches.

No. of Specimen.	Stress Lbs. per sq. inch.	No. of Revolutions.	Elastic Change.	Remarks.
9	36,000	968,000	No.	Broke near box.
10	32,000	1,410,000	No.	Broke.
11	26,830	5,941,000	No.	Broke inside box, at splinter.
12	24,000	10,577,000	No.	
. . .	26,000	10,071,000	No.	
. . .	27,000	5,285,000	No.	
. . .	28,000	4,701,000	No.	
. . .	29,000	5,235,000	No.	
. . .	30,000	4,522,000	No.	
. . .	32,000	1,066,000	No.	Broke at splinter.

3. BESSEMER STEEL.

Elastic limit = 41,600 pounds per square inch. Tensile strength = 68,100 pounds per square inch. Elongation = 26.4 % in 10 inches.

No. of Specimen.	Stress Lbs. per sq. inch.	No. of Revolutions.	Elastic Change.	Remarks.
13	36,000	1,271,000	No.	Broke where clamp was attached.
14	36,000	1,805,000	No.	Broke where clamp was attached.
15	36,000	2,489,000	No.	Broke in slight indentation.

4. OPEN-HEARTH STEEL.

Elastic limit = 50,000 pounds per square inch. Tensile strength = 81,000 pounds per square inch. Elongation = 22 % in 10 inches.

No. of Specimen.	Stress Lbs. per sq. inch.	No. of Revolutions.	Elastic Change.	Remarks.
17	32,000	1,352,000	No.	Broke in slight indentation.
18	32,000	11,370,000	Not observed.	
. . .	34,000	5,266,000	Not observed.	
. . .	36,000	6,982,000	Yes.	Broke at dent made by clamp.
19	36,000	7,686,000	Yes.	Broke at shoulder.
20	32,000	2,527,000	No.	
. . .	34,000	22,816,000	Yes.	
. . .	36,000	13,576,000	Yes.	
. . .	38,000	2,263,000	Yes.	Not broken.

5. SOFT STEEL.

Elastic limit = 28,000 pounds per square inch. Tensile strength = 62,600 pounds per square inch. Elongation = 26.4 % in 10 inches.

No. of Specimen.	Stress Lbs. per sq. inch.	No. of Revolutions.	Elastic Change.	Remarks.
21	32,000	4,400,000	Yes.	
. . .	34,000	5,300,000	Yes.	
. . .	36,000	4,700,000	Yes.	Not broken.

THE THEORY AND PRACTICE OF TANNING.

By WALTER J. SALOMON.

Read May 26, 1892.

I FEEL indeed highly honored to have been called upon to speak before your society as a representative of an industry which has been known from time immemorial, is to-day one of the most powerful industries of the world, though of a modest bearing, and will be connected with mankind as long as human beings inhabit this earth. Leather manufacture and its collateral branches take fourth place in the list of manufactured products of the world, iron, wool and cotton alone taking precedence. The dressing of leather extends centuries and centuries back. Herodotus, the historian, speaks of the Libyan women wearing goatskins stripped of hair and covered with vermilion. The Bible mentions the leathern girdles of Elijah and John the Baptist. In the Mosaic account of the tabernacle we find reference to the rams' skins dyed red; while the Gordian knot, made of leathern thongs, was cut about 330 B.C. On the doors of the Rochester (England) Cathedral, there were numerous skins of pirates; and so we can quote illustration after illustration showing the great age of leather manufacture in different shapes and forms. But we shall turn aside from retrospection and view the leather of to-day, its mode of manufacture, the results obtained and the why and wherefore of tanning.

First, what is leather? Leather is the result of the half chemical, half mechanical combination of the albuminous hide fiber and a substance which preserves the hide or skin and renders it pliable, thereby making it useful in the arts and manufactures. A great many different kinds of hides and skins are used in the manufacture of leather — cowhides, calfskins, horsehides, goatskins, sheepskins, kangaroo, alligator, lizard skins, etc. These hides or skins are purchased in different states; some are dry, some green — that is, just as they are taken from the animal — and some in the green salted state to prevent decomposition in shipping.

Right here it will be interesting to become acquainted with the structure of the hides and skins used by tanners. The hide may be

divided into three parts; namely, the epidermis, the coriin or cutis — or better still, the actual leather hide — and the lower flesh structure. The epidermis is totally removed in the work of preparing the hide for the actual tanning process; and the lower flesh structure is, as a rule, also removed little by little at different stages until we have the leather ready for the market composed wholly of the coriin or cutis. The study of the formation and situation of hide fiber with the aid of the microscope is of great interest and a source of pleasure to the student. It is a remarkable fact that, as we divide or class the living animals according to their nature, in an exactly coinciding way can we class the same animals according to their hide fiber structure. Just as we class the alligator, snake and lizard in the reptiles on account of their similar mode of living, appearance, etc., so we find that they resemble each other even more in their fiber structure. The fiber of these reptiles is so much alike that it is almost impossible to distinguish any difference under the microscope. Again, the structures of the cowhide, horsehide, calfskin, deerskin, etc., resemble each other greatly, being of a looser nature than the fiber of reptiles. But in all hide structure we have the same method of growth and trend as in that of the development of the bark of trees. The lower flesh structure is always of a loose nature, consisting, more or less, of loose bundles of fiber interwoven. As these bundles enter the cutis or coriin they become more compact, the weaving becoming of a closer nature; and as they near the grain or papillar the bundles disappear, and the single fibers are woven in a mass that becomes more solid, until it reaches the compactness of a horny grain which withstands the wear to which the leather is subjected. Just as the bark on trees is worked off and replaced by younger layers from the wood, so is the grain on the living animal continually replaced by fiber from the lower portions of the hide.

Leather is commonly divided into two classes; namely, sole and upper. We will first treat of upper leather. When the hides are received in the tannery they are soaked in water; this soaking removes all blood, salt and lymph substance, and softens the flesh still remaining on the hide so that it may be easily worked off with a knife. After removing the superfluous flesh the hides are resoaked for a period of two days, as a rule, and then placed in the lime. The lime is simply a solution of calcium hydrate or ordinary quicklime in water, and, like all alkalies, has the property of dissolving albuminous substance

and distending fibrous substance. Upon this property is based the process of liming hides, as the action of the lime is a solvent one throughout, resulting in the loosening of the hair roots and the removal of the epidermis. The lime actually divides the fibers into numerous smaller fibers, a fact which is absolutely proven by the microscope. All of this work is done in the department called the "beam house;" so called, evidently, from most of the work being done on beams. It will be seen that the tendency throughout all this work has been to cleanse the hide and hide fiber, and to remove all unnecessary flesh substance, leaving naught but the real hide substance or coriin. Heavy hides are usually limed from four to five days; but light skins of which pliability and elasticity are required are limed from eight to fourteen days. Glove leather is sometimes limed from twenty to thirty days.

Now comes an important step; this is the bating process. Before the hides are bated they are washed or rinsed well in water, whereby almost all of the lime is removed. The bate consists of manure, or if the raw material is a light skin — goatskin, for instance — fermented bran. The manures used are chicken, pigeon and dog. In the first place the effect of the manure bate is to dissolve and remove all the unnecessary interfibrous substances, leaving room for a freedom of motion of the fiber, and facilitating the entrance of the tannin molecule. The effective principles of the manure bate are pepsin and pancreatin, substances which are formed in the body of the animal. While in Vienna last year I had occasion to make a comparative analysis of the strength of the various manures used by tanners, and I found that, taking chicken manure as 1, pigeon manure was 2, and dog, $2\frac{1}{2}$. The hide is put in a warm mixture of manure and water, and digested, as it were, until the hide is found to be "low" enough, or, in other words, digested to such an extent that a prolongation of the process would damage the grain or surface of the hide. This action of the bate may be prettily illustrated by taking an unclean piece of wet linen, halving it, washing one half and hanging both pieces out to dry. Upon examination the unclean piece will be found to have dried stiff and the washed piece to be very much softer. This is due to the untrammeled freedom of motion of the clean fiber. It has been very generally supposed that the purpose of the bate is to remove the lime, but as a rule the lime has been removed in the previous rinsings. Should small quantities of lime remain in the hide

they may be dissolved out in the bate, as sulphuretted hydrogen is usually present and transforms the lime into sulphide of calcium, which is easily soluble in water. The time of bating varies from four hours to a day and night.

Now, as to the bran bate and drench. The bran is usually set with warm water a day or two before it becomes necessary to use it. This brings about fermentation, in the course of which lactic, acetic and some butyric acids are formed. The amount of acid varies from $\frac{1}{2}$ per cent. to $1\frac{1}{4}$ per cent. These acids will dissolve or remove lime, although lactic acid only suspends it; but the effective principle is not based upon this, but upon the plumping and distention of the fiber, thereby again preparing the skin for the actual tanning process. In fact, the test of the tanner is to make a sort of small balloon of the skin and press the inclosed air out, the ease with which this is done being used as a guide to judge the arrival at the wished-for result; namely, a porous, plump skin. An important factor in both of these bating systems is the action of those infinitely small animalculæ, of which we know much, but actually very little — the bacteria. The effect of bacteria on the whole process of tanning is, in fact, of great importance, and furnishes a field for not only very interesting study, but also of practical research, with profitable results to the successful student. In the bates the actions of the bacteria are absolutely uncontrollable, and this is the reason why this stage is so very difficult and requires constant watchfulness. The least change of temperature has an effect. For instance, a bate is placed at say 100° Fahrenheit in July. Now, in the ordinary course of events, the day temperature would be between 80° and 100°, and we might expect at night a temperature of about 70°. But should the night, instead of being cool, be close and warm, say about 80° to 95°, this would, firstly, increase the working powers of the pepsin, as the bate would not cool so quickly, and the greater the temperature the greater the dissolving power; secondly, the bacteria would propagate themselves at an enormously high rate, as a temperature of 90° to 100° is the ideal one for the propagation of these animalculæ. After the leather has been digested to an extent which is most satisfactory for that purpose it is intended to be used for, it is removed from the bate and "slated;" that is, the hide is worked out with a slate set in a wooden handle. This removes all the so-called "impurities," which are really the interfibrous substances in solution and suspension. The hide is then ready to begin the process of actual tanning.

Now, as to sole leather. Hides suitable for this kind of leather are only the heavy cowhides and steer and bull hides. The hides are soaked in the same way; but many, instead of being limed, are "sweated" to remove the hair. Sole leather must be of a firm nature; therefore it is not necessary to have freedom of motion of the fiber, and consequently liming is done away with. The sweating is accomplished in a tight room which is full of vapor; this softens the hair roots, and within four or five days it is possible to brush all the hair off. Again, bating is unnecessary, and they are simply "wheeled" in water and then are ready to tan.

Right here it may be interesting to discuss the tanning materials in use throughout the world. Nature has again been great in her wisdom, for look where you will, from the heart of the United States or Europe to the interior of Africa, you will find substances containing available tannin in quantity. In the United States our main tanning materials are hemlock bark and oak barks, although other materials are used, which come almost totally from foreign countries. England produces only oak bark; France, oak bark and pine bark; Germany, the same; Austria-Hungary, the same with the addition of knoppern, a small excrescence on branches, the result of the sting of an insect; Asia Minor, galls; India, catechu; Indo-China, gambier; Australia, mimosa bark, etc. There are hundreds of other tanning materials, but I do not wish to weary you by going into further details on this subject. The tannin contained varies from 7 to 70 per cent., and each and every one has its distinct color effect. Some tannins color red, others yellowish; again, some give a purple tint, others brown, etc. Some barks make a firm leather, some a loose, pliable stock; and as there is a continual international traffic in these materials, it has become the task of a good tanner to produce the best results in color and weight and firmness with all of them at his disposal.

We now arrive at a step of great interest. This is the actual process of tanning, in its practical as well as its theoretical phase. By careful study and continual examination of specimens with the aid of the microscope, the following conclusion as to the manner of tanning a hide and the entrance of tannin into the fiber is reached. The tannin molecules in solution in the bark liquor attack the hide from both sides, and first tan the outside fibers; then they are redissolved and go on to the next inner layers, their places being taken by other molecules. Now they leave the second fibers and go to the third,

being again replaced, and so on, until the opposite armies of molecules meet, when the hide is tanned. The outside fibers are consequently tanned and retanned thousands of times. There is a condition which a tanner calls "dead tan," and this is based upon the total filling up of all the interfibrous canals, glands, etc. Tanners whose object it is to produce good-weight results usually try to reach this "dead-tan" point as nearly as possible and practicable. This theory may seem a little odd at first, but, as I said before, continual observation leads us to this conclusion.

Now, as to the practical side of this process. The bark or tanning material is placed in a wooden tank, or "leach," as the tanners call it, and water being pumped on it, a decoction is made. This gives us the so-called bark liquor, and in this liquor the hide is tanned. It takes all the way from six days to nine months to tan ordinary hides and skins, while a walrus hide requires a time of three years; this variation being caused by the different purposes for which leather is used, and the different peculiarities and qualities consequently necessary. In the case of light skins, by keeping them continually in motion by the aid of the paddle wheel, rockers, etc., so as to admit of the easy entrance of tannin, we are enabled to tan much more quickly; but these skins are used for light shoes and other light work for which no excessive firmness or solidity of the leather is needed. Heavy leather is, as a rule, "struck through," that is, colored through with tannin, and then placed in strong liquors or laid away in a pit and strewn with bark to tan for weight.

Of late years quite an industry has sprung up in the manufacture of extracts of bark for the benefit of tanners far away from bark regions, or to insure the tanner against a possible shortage of bark. The extracts are made by boiling the bark or tanning material with water in the open air or in a vacuum, and then boiling down to a thick mass containing about four to six times the strength of an equal quantity of bark. This, of course, is of great assistance to the tanner. But the correct use of these extracts is not quite as well understood by some tanners as might be wished.

There are also a number of other materials besides bark used for preserving leather. One might arrange tanning materials in a row in the order of their tanning ability, with tannins at one extremity, coloring matters in the middle, and aniline, which also preserves leather, as the least effective. It is a peculiarity of all metals of the third

chemical group, namely, iron, chromium, aluminum, zinc, manganese — but nickel and cobalt excepted — that they have the property of entering into a half chemical combination with the fiber by the power called absorption, and thereby so enveloping the fiber that it becomes imputrescible. Alum tanning in different forms and processes has been in use for centuries, but chrome tanning, which is, as a rule, brought about by a soluble chrome salt being soaked into the skin and then precipitated on the fiber by reduction, has been in practice only since the year 1856. This tannage, as it is called, is being used to a large extent at present in the manufacture of glazed kid. Another tannage is made through the dongola process, which is a combination of the mineral tannage, the tannin tannage and the addition of oil or grease, usually in a saponified form. Again, we have the oil tannage for chamois and buckskin. Oil tanning is done by working the skins from the bate, usually bran, in oil, and removing the superfluous oil by soda or potash, or other alkali.

There has been much discussion within the last few years as to the real value of electric tanning, its real effect on the hide fiber and its value in assisting and facilitating the tanning of leather. So far there has been no success made of this especial branch, although it has been tried in numerous places. A Parisian firm has been making numerous experiments for the last three or four years, but as far as I have been able to learn, has met with dismal failure. The idea that electricity can have any effect on tannin in any other way than to precipitate the phlobaphenes, that is, undesirable coloring matters, seems to me extremely doubtful. I have seen a number of experiments made with the aid of the different poles used, such as platinum, tin, gold and copper, the peculiarity being that as the poles differed the color differed, one giving a bright and beautiful color, others giving darker colors. This may be of value to some tanners of upper leather or sole leather who desire to obtain excellent color results. That the electricity has any effect upon the hide fiber is exceedingly doubtful; and as to its quickening the tanning, it cannot do so except indirectly by precipitating the undesirable coloring matter, thus leaving an easily soluble tannin which will pass into the hide at a quicker rate. But it requires constant care and study in order to obtain satisfactory results. Possibly new things may develop which may be of value, but for the present we can hardly call it an important phase of the leather industry.

There are thousands of ways of finishing leather after it leaves the tan, so that it will be impossible for us to go into this step any further than to say that most of the upper leather is colored black, worked out well to flatten it, and after being oiled is placed on the market.

It often seems strange to a person not connected with the leather trade that enough hides and skins can be procured to meet the demand for the many purposes that leather is used for; but instead of a shortage we have at present a large quantity in the market for which buyers are hard to find. The American leather trade is increasing yearly. Formerly we imported large quantities of leather, but to-day our import list has dwindled down to almost nothing, while we in turn are doing a very large export trade.

Before closing I would like to remark that all of the before mentioned theories have been made from actual observation in practice, not, as has been so often the case, by making theories and fitting practice to them.

The present opportunity to discuss the establishment of a technical school for the tanning industry is so good that I will pause a few moments on this subject. In Europe, and especially in this case Austria, they have carried the plans and ideas of technical education to a very successful point. You will find there schools and institutions of all special lines of industry; among them, most elaborate schools of forestry, inclusive of bark culture and economical production, and a most successful tanning school. The advantages of this technical education undoubtedly are apparent to this society. The leather industry of this country has reached a point where it must avail itself of the glorious advantages that the correct and conscientious application of science is capable of giving it. The associated manufacturers have appointed a committee to further this plan of the establishment of a school, but this committee have not met with the success in a pecuniary way that they hoped for. Now, it may be possible that such an annex or department of this Institute could be founded here in the heart of the leather country, and the possibilities of the plan may furnish food for reflection for your society.

AN INDEX TO THE LITERATURE OF ANGELIC AND TIGLIC ACIDS FROM 1842 TO 1892.

By HENRY P. TALBOT, Ph.D.

Among the large number of organic compounds which have excited the interest of chemical investigators during the last half century, few have done so to such a degree as have angelic and tiglic acids. This may largely be attributed to the fact that these compounds have, until recently, resisted all attempts to discover their molecular structure or the exact relation in which they stand to each other. Even to-day these problems have not been wholly solved; for while it is generally conceded that these two acids present a well-marked instance of geometrical isomerism, it cannot be asserted that this fact is decided beyond question; nor has the geometric structure of either acid been so positively determined as to preclude the necessity for further research.

The number of investigators who have made these compounds the subject of their researches is large, and the literature relating to them which has accumulated during fifty years is considerable in amount. It has seemed to the writer that a compilation of this literature, scattered as it is through many journals and written in several languages, would be an assistance to future workers in this field.

The labor attending the search for information relating to angelic acid is materially increased by the confusion of names in the earlier literature, the name angelic acid having been applied to compounds whose properties do not correspond to those of the acid which now bears that name. In the accompanying index such cases are indicated by interrogation marks placed against the name angelic acid.

It is also necessary to bear in mind, when studying the literature of tiglic acid, that for a number of years that acid was only known as methylcrotonic acid, the name tiglic acid not appearing until 1870.

The history of these interesting compounds is outlined in the following:

Angelic acid has been longer known than tiglic acid. It was first isolated by Buchner (1842) from the roots of the *angelica archangelica*, and received from him the name which it now bears. Buchner describes this new acid with some detail, but views it more from the standpoint of the pharmacist than that of the chemist, and makes no hypothesis as to its structure.[1]

Meyer and Zenner, in 1845, and Gerhardt, in 1848, both published analyses of angelic acid which correspond to the empirical formula $C_5H_8O_2$; but they, again, offered no suggestion as to the probable molecular structure of the compound.

The work of Frankland and Duppa, published in 1865, describes the first of the attempts to determine upon a structural symbol for angelic acid, and also begins the history of tiglic acid under its structural name, methylcrotonic acid. By the action of phosphorus trichloride upon ethyl metho-ethoxalate they prepared an acid, the properties of which they described (and which were later found to correspond with those of tiglic acid), and to which they gave the name methylcrotonic acid. From the origin and method of preparation of this compound, its structure should correspond to the symbol $CH_3-CH=CCH_3-COOH$.

Frankland and Duppa found it to be isomeric with angelic acid; and that, like the latter, when treated with potassium hydrate, it yielded acetic and propionic acids. This would, according to their views, limit the possible symbols for angelic and tiglic acids to the following:

$$\begin{matrix} CH_3 \\ CH_3 \end{matrix}\!\!>C=CH-COOH, \text{ and } CH_3-CH=CCH_3-COOH.$$

Of these the latter is the probable symbol of methylcrotonic acid, as has been shown, which leaves the first as the only possible symbol for angelic acid, unless, as they said, "we assume some unknown cause for isomerism."

Between 1865 and 1870 but little work was done upon these acids. Jaffé acted upon angelic acid with bromine, and made a partial study of the addition-products; but no important theoretical deductions were

[1] In an abstract of a recent article by Kondakoff [Ber. 25 (1892), 34 Ref.], the original of which is published in the J. Russ. Chem. Soc., the statement is made that Buchner regarded angelic acid as α-ethylacrylic acid. The writer has been unable to confirm this statement.

made from the results of his work. It may be remarked here that both angelic and tiglic acids have been found in other natural products than *angelica*, notably in the oil of camomile. References to all of this work are to be found in the index, although not all of it is mentioned in this historical sketch.

In 1870 Geuther and Fröhlich prepared an acid from croton oil to which they gave the name tiglic acid, at the same time calling attention to its isomerism with the methylcrotonic acid of Frankland and Duppa, and suggesting the possible identity of the two compounds. This question of identity was not, however, settled until 1878, in which year Schmidt and Berendes established it beyond question. From that year the name tiglic acid has been more generally used than methylcrotonic acid.

Additional and convincing proof of the structure of this compound was furnished by Wislicenus and Rohrbeck (1887), who prepared it synthetically by the withdrawal of water from α-methyl-β-oxybutyric acid.

In 1877 Demarçay investigated the bromine addition-products from angelic acid, and from the results of his work was disposed to represent the structure of the angelic acid by the symbol

$$CH_3-CH-CH-COOH.$$
$$\quad\quad\quad

fact that the earlier workers, who obtained their angelic acid from that source, may have dealt with an impure article. With the hope of being able to throw new light upon the structure of angelic acid, Fittig and Pagenstecher (1879) investigated the dibromides and hydrobromides of this and of tiglic acid. They were unable to detect either physical or chemical differences between the corresponding compounds of the two acids.

Fittig, when commenting upon this work, pointed out that the identity of the hydrobromides may be explained by assigning to angelic acid the symbol

$$CH_3-CH_2-\overset{CH_2}{\overset{//}{C}}-COOH.$$

But the assumption is there made that when tiglic acid is acted upon by hydrobromic acid the bromine atom takes the *a*-position as regards the carboxyl group, which has since been disproved. Moreover, the symbol failed to explain the identity of the dibromides, and was, therefore, not more satisfactory than those which had already been proposed.

Schmidt, in 1881, was the next to contribute to this subject. He showed that both angelic and tiglic acids yield the same reduction-products upon treatment with hydriodic acid, namely, methylethylacetic acid. He did, however, note a difference in the hydro-iodides formed by the moderate action of hydriodic acid upon the two unsaturated acids, although he did not investigate these hydro-iodides fully. This may be cited as the first instance in which different products had been obtained by the action of reagents upon the organic compounds in question.

Schmidt proposed as a possible symbol for angelic acid, the following :

$$CH_2=CH-\overset{CH_3}{\overset{/}{C}}H-COOH.$$

This formula is, however, at variance with the fact that acetic and propionic acids are formed by oxidation with potassium hydrate — a fact which has been well established. Fittig also pointed out later (1882) that neither the symbol proposed by Schmidt nor that proposed by him (as already given) can represent the structure of the molecule. He confirmed the statement made by Schmidt that the hydro-iodides of the two acids differ as regards physical properties, but stated that they yielded identically the same products upon treat-

ment with sodium carbonate and that this product was a pseudo-butylene.

Assuming the correctness of Schmidt's symbol, the hydro-iodide formed would correspond to the symbol $CH_2I-CH_2-CHCH_3-COOH$, and the hydro-iodides from Fittig's symbol would be represented by

$$CH_3-\underset{\underset{COOH}{|}}{CI}-CH_2-CH_3 \quad \text{or} \quad CH_2I-\underset{\underset{COOH.}{|}}{CH}-CH_2-CH_3$$

Of these, the first should yield a valero-lactone upon treatment with water; the second, upon treatment with sodium carbonate, should yield an oxy-acid; and the third a butylene, but not the pseudobutylene obtained from tiglic acid hydro-iodide, which has the structural symbol $CH_3-CH=CH-CH_3$. Since, according to Fittig, the butylenes formed from the two hydro-iodides were identical, none of these symbols could be correct.

The action of potassium permanganate upon tiglic and angelic acids has been investigated by Beilstein and Wiegand in 1884, and by Kondakoff in 1888; but the results of their work simply confirmed the structural similarity of the two acids, no difference in their behavior having been detected.

The outline already given presents briefly the results of the investigations carried on before 1887, at which time Wislicenus turned his attention to the solution of the problem which these two isomeric compounds offered. In 1874 van't Hoff and Le Bel presented to the scientific world their theory regarding the arrangement of the atoms within the molecules of organic compounds. Wislicenus had, as van't Hoff states, by his remarks upon the isomerism of the lactic acids, furnished the incentive to further thought which finally developed into the latter's theory of three-dimension formulas. Van't Hoff himself suggested that his theory would furnish a means of explaining many cases of isomerism which the previously accepted hypotheses were unable to deal with. It was Wislicenus who, later on, developed the theory of van't Hoff, and afterward perfected the methods for the treatment and detection of geometrically isomeric bodies which have been of great value in the study of this class of compounds.

In 1887 Wislicenus, basing his assertion upon the behavior of crotonic and isocrotonic acids, stated his belief that angelic and tiglic acids would be found to be geometric isomers. In 1888 Wislicenus and

Pückert re-examined the dibromides of these acids, which Fittig and Pagenstecher had pronounced identical, and found that the dibromides did not yield the same pseudobutylenes upon treatment with sodium carbonate, but that the hydrocarbons formed were geometric isomers. From a line of argument given in detail in the original article [see reference (60) in the index], based upon the results of Pückert's work, Wislicenus assigns to angelic acid the symbol

$$\begin{array}{l} CH_3-C-H \\ CH_3-\overset{\|}{C}-COOH, \end{array}$$

and to tiglic acid the symbol

$$\begin{array}{l} H-C-CH_3 \\ CH_3-\overset{\|}{C}-COOH. \end{array}$$

These symbols are also in accordance with those assigned to isocrotonic and crotonic acids, the latter of which corresponds in its behavior to tiglic acid, and received the symbol

$$\begin{array}{l} H-C-CH_3 \\ H-\overset{\|}{C}-COOH. \end{array}$$

To Wislicenus, then, is due the credit for the first experimental evidence in favor of geometrical isomerism as an explanation of the behavior of the two acids under consideration.

It is interesting to note that Ostwald's deductions from a series of determinations of the affinity constants of these acids, made in 1889, support the views held by Wislicenus. Ostwald found that tiglic acid is the weaker of the two acids, which corresponds to the symbol already given, in which the methyl group attached to the upper carbon atom is nearer the carboxyl group than in angelic acid. The methyl group is generally more positive than the hydrogen atom alone, and exerts a greater influence upon the carboxyl group. This theory is also supported by the crotonic and isocrotonic acids, the former (corresponding to tiglic acid) being the weaker of the two.

Additional support has been given to the assumption of Wislicenus that these acids furnish an excellent example of geometrical isomerism by the work of Mellikoff and Petrenko-Kritschenko (1890), who have formed and isolated four chlor-oxy-valerianic acids resulting from the action of hypochlorous acid upon the double-bonded organic acids, in exact accordance with the theory.

The writer also made a more thorough study of the hydro-iodides of these acids than that made by Schmidt or Fittig, to which reference has already been made. That the hydro-iodide from angelic acid is a distinctly different body from the tiglic acid hydro-iodide there can be no question, and a study of these compounds with a view to the confirmation of the theory of Wislicenus regarding the constitution of the original acids has developed nothing which is at variance with the formulas given.

On the other hand, it must be stated that the correctness of the work of Wislicenus and Pückert has been seriously questioned by Fittig (1891), who reaffirms the validity of his own work with Pagenstecher. The work of Pückert has also been indirectly attacked by Favorsky and Debout, and the latter criticism also affects the work of the writer, and has hindered the publication of the theoretical deductions except as referred to in reference (80) of the index.

Notwithstanding these criticisms of the work done in Wislicenus' laboratory to prove the geometric isomerism between these two acids, the fact remains that the symbols proposed by Wislicenus are the only ones which do not conflict with observed facts. The weight of the evidence is strongly in favor of this theory, and it is to be hoped and expected that new proofs of this isomerism will soon be furnished.

Finally, a few words in explanation of the accompanying index are necessary.

The following journals were consulted from their beginnings to April, 1892, inclusive, except as otherwise indicated, or unless publication of the journal ceased before 1892:

American Chemical Journal; Annalen der Chemie; Annales de Chimie et de Physique (1822–1883); Annalen der Physik (Poggendorff) (1822–1877); Archiv der Pharmacie; Berichte der deutschen chemischen Gesellschaft; Bulletin de la Société chimique de Paris; Chemisches Central-Blatt; Comptes rendus de l'Académie des Sciences; Gazzetta chimica italiana; Journal of the Chemical Society; Journal für praktische Chemie; Jahresbericht der Chemie; Jahresbericht der reinen Chemie; Monatshefte für Chemie; Recueil des Travaux Chimiques des Pays-Bas; Répertoire de chimie pure et appliqué; Zeitschrift für Chemie; Zeitschrift für physikalische Chemie.

In addition to the above the following text-books have been consulted, although it has not been thought best to include the page references in the index: Beilstein (second edition, 1890), Gmelin, Gerhardt, Kekulé, Kolbe-Von Meyer (Graham-Otto), Roscoe and Schorlemmer, and the dictionaries of Fehling, Watts and Wurtz.

The abbreviations used are those recommended by the Committee on the Indexing of Chemical Literature of the American Association for the Advancement of Science.

Each journal was consulted by means of the general indexes for a series of years, where these existed, otherwise through the indexes for each year or volume. It is to be remarked that in some cases, notably those of the *Archiv der Pharmacie* and the *Comptes rendus*, the general indexes are of such a character that, unless the acids in question form a part of a title or occupy a prominent place in any article, it is impossible to discover that they are mentioned at all.

It is probable that a few references of minor importance may have been overlooked, but it is believed that the index is practically complete to April, 1892, as regards the journals and text-books mentioned.

The references marked by an asterisk were not accessible to the writer, and are classified wholly from the information obtained from abstracts of their contents given in other journals. In each case the original article is the first reference given, and all references following the words "in abstract" are less complete than the original article. No attempt has been made to make the list of abstracts wholly complete, but in most cases in which these abstracts occur in several languages one reference in each language has been given. The references to the *Jahresbericht der Chemie* generally furnish a full record of the journals in which the given article has appeared, and these references are given before those of the abstracts.

The arrangement of the index of subjects is that which suggested itself as convenient, and requires no additional explanation. The order of the references under each division is chronological.

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Wright and Luff. (85) . J. Chem. Soc. **33** (1878), 347; Jsb. Chem. (**1878**), 906; Chem. News. **37** (1878), 246.
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MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
May, 1892.

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†† Compare also Fock (21) and Talbot (81) for measurements of the crystals of the hydro-iodides of angelic and tiglic acids.

PROPOSED NEW FORMULA FOR YELLOW PINE POSTS.[1]

By JAMES H. STANWOOD, S.B, Instructor in Civil Engineering.

Received June 8, 1892.

Believing that the formula of C. Shaler Smith, given in Trautwine, gives too large values for yellow pine posts, and having the usual objection to the "step" formula, the writer, for his own information and use, has taken the trouble to plot the values of all the tests on *full size* sticks made at the Watertown Arsenal and printed in the government reports.

From the drawing herewith the straight line formula

$$S = 5{,}000 - 43\tfrac{1}{3}\,\frac{l}{d}$$

was easily deduced, which represents the average of all the tests.

For the average of the *lowest* values in each set of tests the formula

$$S = 4{,}250 - 43\tfrac{1}{3}\,\frac{l}{d}$$

was found. The line representing this formula chanced to be parallel to the first one. With this latter equation as a basis, the working formula

$$S = 1{,}000 - 10\,\frac{l}{d}$$

gives a factor of safety of 4.25 approximately. This very simple equation is easily memorized, and by its use the safe load for a yellow pine post may almost instantly be worked out "in the head."

The coefficient of $\frac{l}{d}$ being about one one-hundredth of the first term, any factor other than 4.25 may as readily be used; thus

$S = 800 - 8\,\frac{l}{d}$ for a factor of 5 approximately.

$S = 1{,}400 - 14\,\frac{l}{d}$ for a factor of 3 approximately, etc.

For sake of comparison, the formulæ of C. Shaler Smith and Mr. Ely have been plotted.

[1] Copyright, 1892.

For those who prefer not to depart from the strict column formula of the form

$$S = \frac{k}{1 + \frac{1}{a}\frac{l^2}{d^2}}$$

the following:

$$S = \frac{4{,}000}{1 + \frac{1}{2{,}500}\frac{l^2}{d^2}}$$

may be used, which, if plotted, will be found to represent the average of the lowest values.

In each of the above formulæ

l = length in inches.
d = smaller diameter in inches.

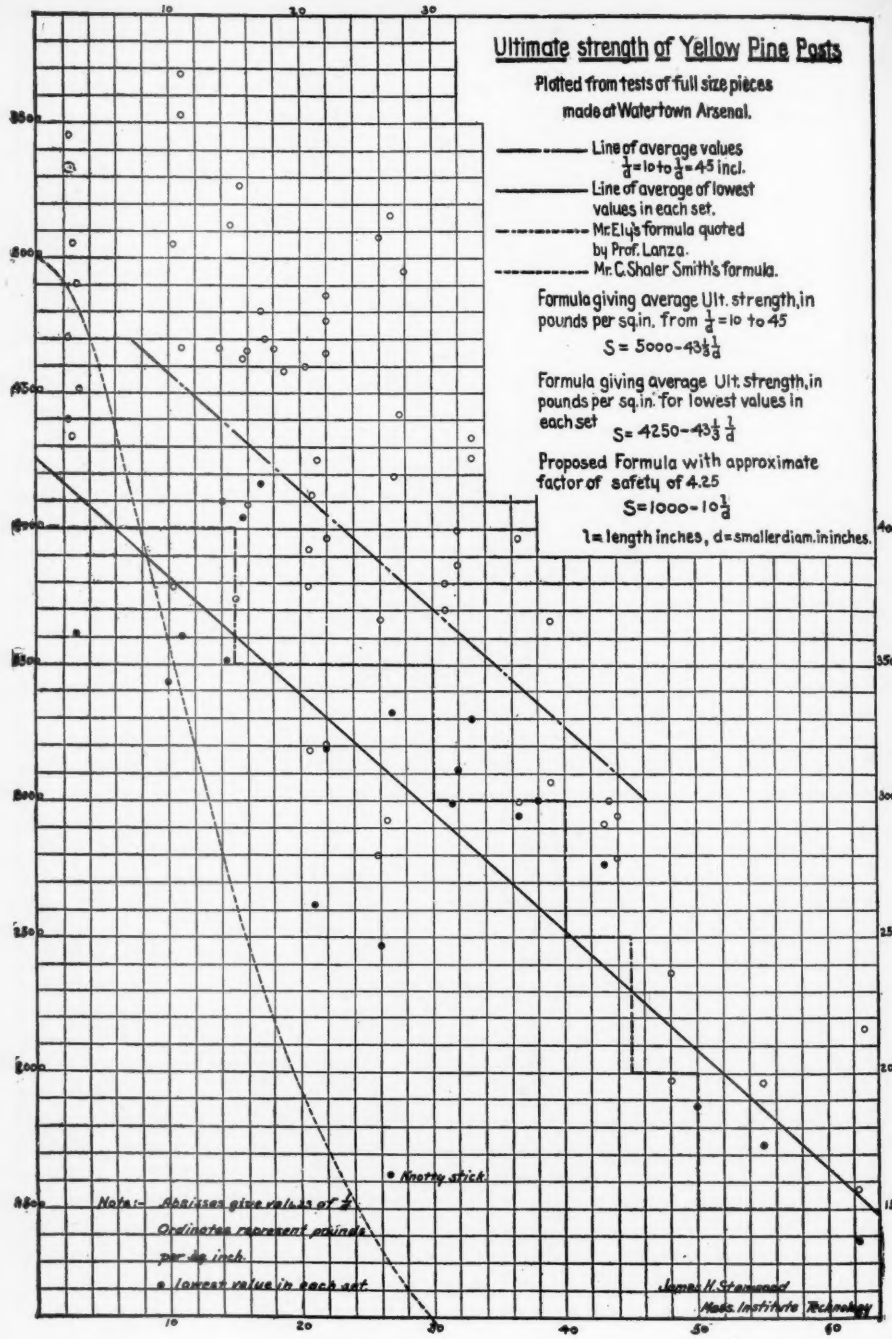
From the expression

$$S = 1{,}000 - 10\frac{l}{d}$$

the table of safe loads has been computed.

Trusting that this will be of use to others, it is respectfully submitted to the profession.

Since making this drawing, the recent experiments of Kirkaldy on wood columns of fairly large size have been applied to the proposed formula, and found to agree quite well with it.


Ultimate strength of Yellow Pine Posts
Plotted from tests of full size pieces made at Watertown Arsenal.
Line of average values $\frac{l}{d}$ = 10 to $\frac{l}{d}$ = 45 incl.
Line of average of lowest values in each set.
Mr. Ely's formula quoted by Prof. Lanza.
Mr. C. Shaler Smith's formula.
Formula giving average Ult. strength, in pounds per sq. in. from $\frac{l}{d}$ = 10 to 45
$S = 5000 - 43\frac{1}{3}\frac{l}{d}$
Formula giving average Ult. strength, in pounds per sq. in. for lowest values in each set
$S = 4250 - 43\frac{1}{3}\frac{l}{d}$
Proposed Formula with approximate factor of safety of 4.25
$S = 1000 - 10\frac{l}{d}$
l = length inches, d = smaller diam. in inches.
* Knotty stick
Note:- Abscisses give values of $\frac{l}{d}$
Ordinates represent pounds per sq. inch.
* lowest value in each set
James H. Sturgeon
Mass. Institute Technology

Safe Loads, in Pounds, for Yellow Pine Struts.

Computed from the Formula $1000 - 10\frac{l}{d}$, *l = length in inches d = smaller diameter in inches. This is approximately the same with a factor of safety of 4½, as the Formula* $4250 - 43.3\frac{l}{d}$, *which was obtained by plotting all experiments obtainable, on full-sized sticks, made with the Government Testing Machine at Watertown Arsenal and represents the average of all the lowest breaking weights in each set of tests.*

J. H. Stanwood, Mass. Institute of Technology, 1891.

Size	6 Ft.	8 Ft.	10 Ft.	12 Ft.	14 Ft.	16 Ft	18 Ft.	20 Ft.
4 x 4	13 100	12 200	11 200					
4 x 6	19 700	18 200	16 800					
4 x 8	26 200	24 300	22 400					
4 x 10	32 800	30 400	28 000					
4 x 12	39 400	36 500	33 600					
6 x 6	31 800	30 200	28 800	27 400	25 900	24 500		
6 x 8	42 300	40 300	38 400	36 500	34 600	32 600		
6 x 10	52 800	50 400	48 000	45 600	43 200	40 800		
6 x 12	63 400	60 500	57 600	54 700	51 800	49 800		
6 x 14	74 000	70 600	67 200	63 800	60 500	57 100		
6 x 16	84 500	80 600	76 800	73 000	69 100	65 300		
8 x 8	58 200	56 300	54 400	52 500	50 600	48 600	46 700	44 800
8 x 10	72 800	70 400	68 000	65 600	63 200	60 800	58 400	56 000
8 x 12	87 400	84 500	81 600	78 700	75 800	73 000	70 100	67 200
8 x 14	101 900	98 600	95 200	91 800	88 500	85 100	81 800	78 400
8 x 16	116 500	112 600	108 800	105 000	101 100	97 300	93 400	89 600
8 x 18	131 000	126 700	122 400	118 100	113 800	109 400	105 100	100 800
10 x 10	92 800	90 400	88 000	85 600	83 200	80 800	78 400	76 000
10 x 12	111 400	108 500	105 600	102 700	99 800	97 000	94 100	91 200
10 x 14	129 900	126 600	123 200	119 800	116 500	113 100	109 800	106 400
10 x 16	148 500	144 600	140 800	137 000	133 100	129 300	125 400	121 600
10 x 18	167 000	162 700	158 400	154 100	149 800	145 400	141 100	136 800
12 x 12	135 400	132 500	129 600	126 700	123 800	121 000	118 100	115 200
12 x 14	157 900	154 600	151 200	147 800	144 500	141 100	137 800	134 400
12 x 16	180 500	176 600	172 800	169 000	165 100	161 300	157 400	153 600
12 x 18	203 000	198 700	194 400	190 100	185 800	181 400	177 100	172 800
14 x 14	185 900	182 600	179 200	175 800	172 500	169 100	165 800	162 400
14 x 16	212 500	208 600	204 800	200 900	197 100	193 300	189 400	185 600
14 x 18	239 000	234 700	230 400	226 100	221 800	217 400	213 100	208 800
16 x 16	244 500	240 600	236 800	233 000	229 100	225 300	221 400	217 600
16 x 18	275 000	270 700	266 400	262 100	257 800	253 400	249 100	244 800
18 x 18	311 000	306 700	302 400	298 100	293 800	289 400	285 100	280 800
	6 Ft.	8 Ft.	10 Ft.	12 Ft.	14 Ft.	16 Ft.	18 Ft.	20 Ft.

KAOLIN IN ASHLAND, MASS.

By FREDERICK S. HOLLIS, S.B.

Received June 11, 1892.

Basin six, which is being built for the increase of the Boston Water Supply, is formed by building a dam across the valley of Indian Brook at a point about two and a half miles west of the Ashland station.

Indian Brook rises just west of Hopkinton Village, at an elevation of about 380 feet, and for the first two miles of its course runs almost north, following the valley. At this point, however, the direction of the valley changes almost abruptly to east and west, and the brook follows it, running 10° to 15° north of east, which direction it follows, with the exception of one detour toward the south, until it joins the Sudbury River.

The hills which form the valley rise to a height of from 400 to 500 feet, and although mostly covered with drift, there are numerous outcrops showing glaciated rock surfaces. The axes of the hills, as well as the contours on either side of the valley where the dam is built, run approximately east and west, while the outlines of most of the hills in the vicinity are irregular, and do not trend in any one direction.

As a guide in selecting a site for the dam, borings were made at a number of places extending across the valley. It was found that there was considerable overlying drift, and that it increased rapidly in thickness further down the valley. At the point selected, the bottom of the valley in which the brook runs has an elevation of 240 feet, and it was decided to establish the flow line at 295 feet; so the dam is about 60 feet high in the deepest part of the valley, and 1,600 feet long at the top.

The center of the dam is a wall or core of solid masonry. The trench for this core ran almost exactly north and south, and throughout its entire length the earth was removed down to the surface of

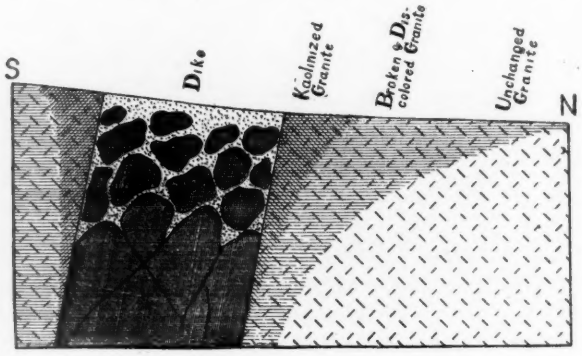
the underlying rock, which is the rather coarse pink granite so common in that locality. At a number of points along this exposure, seams of soft material were found, and through the kindness of Mr. Desmond FitzGerald, engineer and superintendent of the Boston Water Works, I was enabled to examine these on July 27, 1891.

It was evident at first sight that the seams were of two kinds, both as to their composition and their formation. The rock surface of the northern or lee side of the valley slopes rapidly down toward the center, and is very irregular, forming at the upper part of the slope a series of holes, three of which are about ten feet deep. Within these holes, well up on the northern slope, and in a single instance near the beginning of the southern slope, are seams of mica schist. These vary in thickness from those at the top, which are but a few inches, to the three at the bottom, which are from three to five feet. They run northeast and southwest, following in a general direction the joint seams of the rock, and are inclined at an angle of from 20° to 30° from the vertical.

All of these seams are composed of the same dark-colored, fine-grained mica schist; but a large part of the exposed portion has been decomposed, yielding a dark gray product having the same texture as the original rock, but crumbling readily in the fingers. In a few cases the granite which is in direct contact with these seams of schist seemed to be finer and granular. This suggested the possibility of change by contact with the schist; but on careful examination I found that the granite changed independently into this form, which, although crumbly in cases, is probably as firm as when first formed. The only change in the granite that can be attributed to the seams of mica schist seems to be a reddening of the surface. Further down the valley on an exposed rock surface is a seam of schist having the same direction as those exposed in the trench, showing that they are of general occurrence.

The southern or stoss slope, which was more exposed to erosion during the passage of the glacier across the valley, is more gradual, and the surface of the rock has none of the jagged appearance noticed on the northern side. None of the seams of mica schist were observed on this slope, but near the southern end of the dam is a layer of dark-colored rock entirely different from the schist. This is a dike of true eruptive rock, probably diabase from four to five feet wide, running about north 60° east. As exposed in the trench it was much decom-

posed, yielding a loose, black gravel. The decomposition has taken place in the way that is so characteristic of basic dike rocks. The dike rock was first jointed in different directions, yielding roughly cubical blocks; and the decay went on along these joint seams, the corners of the blocks yielding more readily than the flat surfaces, so as to produce rounded stones separated from each other by loose material — the product of their own decay. On breaking a number of these rounded stones the nuclei were found to be of the unchanged dike rock, which was black, rather fine grained and very hard.



The granite intersected by this dike is much cracked for a considerable distance, which could be seen from the material thrown out in digging the trench; and along the wall of the dike the granite is entirely decomposed or kaolinized. This decomposed granite has retained its original form; so that on breaking a piece the quartz, feldspar and hornblende crystals were found to have the same position as in the original rock, and the shape of the feldspar crystals could readily be distinguished, although they are entirely changed to kaolin or white clay.

The change from the granite that is merely cracked to that in contact with the dike, which is entirely decomposed, is gradual and can be easily traced, showing that the granite decayed *in situ*, and that the kaolin is a remnant — probably the lower part of a true sedentary soil. The cracked condition of the granite may be accounted for by the flow of the melted material of the dike up through a fissure in the already formed granite; and the more perfect decomposition along the line of

contact by the fact that the material of the dike, owing to its basic composition, would be decomposed more readily than the granite, thus forming a channel through which water could flow and come in contact with the already cracked or highly jointed granite.

In order to determine the purity of the kaolin, chemical analyses were made; but, on account of the great difficulty in separating a sample, the results are less satisfactory than I hoped they might be. The kaolinized portion is not the result of the decay of a deposit of pure feldspar, nor even of a rock containing large separate crystals of that material, but of the pink Milford granite, containing less than 50 per cent. of feldspar, and that in small, irregular crystals intermixed with and often entirely inclosed by quartz. In taking the first sample for analysis the pieces of kaolinized granite, which were sufficiently moist when collected to form a plastic mass, were allowed to dry, and from freshly broken surfaces the clearer pieces of kaolin were picked out with a sharp pointed knife. This was rubbed between the thumb and finger to separate it from adhering quartz, sifted through a 60-mesh sieve, and dried at 100°C.

The results of analysis are as follows, and for comparison the percentage composition of both pure kaolin and unaltered orthoclase are also given:

	Ashland sample.	Pure Kaolin. Al_2O_3, $2SiO_2$, $2H_2O$.	Orthoclase. $K_2AlSi_6O_{16}$.
Combined water . . .	2.80	13.9	0
SiO_2	82.10	46.3	64.7
Al_2O_3	9.30	39.8	18.4
K_2O	3.90	None, or trace.	16.9
Na_2O	.70	None, or trace.	None, or trace.
CaO	.50	None, or trace.	None, or trace.
MgO	.13	None, or trace.	None, or trace.
Fe_2O_3 and Mn_3O_4 . . .	.65	None, or trace.	None, or trace.

The presence in the Ashland sample of $\frac{2}{9}$ of the amount of K_2O found in unchanged orthoclase, shows the presence of some imperfectly decomposed feldspar. The very large excess of silica and

the correspondingly small amount of combined water are clearly due to the presence of fine quartz which came through the No. 60 sieve in sampling.

In order to get a sample free, if possible, from the admixture of quartz, the clayey portion was separated from a considerable portion of the decomposed granite by levigation with water. This was done by thoroughly mixing a sample with distilled water in a jar about two feet high, and, after allowing to settle for from three to four hours, siphoning off the water with what clay remained in suspension. This was evaporated, and the kaolin thus collected dried at 100°C.

COMPOSITION OF KAOLIN SEPARATED BY LEVIGATION.

Combined water	4.9 per cent.
SiO_2	69.9 "
Al_2O_3	20.6 "
Fe_2O_3	1.3 "
Mn_3O_4	0.1 "

Although the analysis of the sample obtained by levigation gives about twice as much combined water and alumina as the sample obtained by sifting through a 60-mesh sieve, the large excess of silica and the results in combined water and alumina, which are still low, show that there is an admixture of a large amount of fine quartz flour. The amount of combined water in the sample obtained by levigation is 4.9 per cent., or 41 per cent. of what it is in a true clay. For comparison I determined the amount of combined water in a sample of brick clay from the Boston basin, which is a clay owing its origin in a great part to glacial action. It contains 3.4 per cent. of combined water, or only 28 per cent. of the theoretical amount in a true clay.

As to the time when this decomposition of the granite took place, all the evidence seems to indicate that it was mainly if not all preglacial; for the splintered granite alongside of the decomposed portion, and at the same level, has been exposed to the same agencies since glaciation without marked decomposition. At this point the rock is covered with nearly 30 feet of glacial till, which is very compact, forming a hard pan; and throughout this layer are numerous angular fragments of the same granite, broken from neighboring ledges, which have been exposed to the action of infiltrating waters since they were deposited along with the till by glacial action, and their only change is

a discoloration extending but a short distance beyond the surface, caused by the more perfect oxidation of the iron.

The position of the valley favors such a theory; for, as the valley runs east and west, is narrow and has a steep slope toward the north, it is probable that it would soon be filled up with glacial till, over which the ice would pass without coming in contact with or disturbing the surface except along the ridges.

It is evident that all the post-glacial decay must have been accomplished by means of infiltrating water which has filtered through the 30 feet of overlying till; and this must be very slight, for it is situated well up on the southern slope, about 850 feet from the bed of the brook and considerably above it, and well above the peat-covered area. My analyses of the soil, from a position in the valley similar to that above the kaolinized rock, show that there is but little organic matter of any kind except in the superficial covering of loam, which is only from six to nine inches deep.

AMOUNT OF ORGANIC MATTER IN SOIL AT DIFFERENT DEPTHS FROM THE VALLEY OF INDIAN BROOK.

	Loss on ignition.	Per cent. carbon.	Amount of organic matter calculated.
First 6 inches, loam	7.62 per cent.	1.56 per cent.	3.12 per cent.
6 inches to 1 foot, subsoil . . .	4.47 "	.52 "	1.04 "
1½ feet, subsoil	3.48 "	.41 "	.82 "
2½ feet, subsoil	2.48 "	.22 "	.44 "
3 to 3½ feet, subsoil	1.77 "	.13 "	.26 "
3½ to 4 feet, clear sand	.79 "	.03 "	.06 "

THE INSULATION RESISTANCE OF RAIL CIRCUITS IN RAILROAD SIGNALING.[1]

By BERTRAM H. MANN, S.B.

Received July 28, 1892.

For the purposes of railroad signaling by certain systems, the rails of the track are made use of as electric conductors by dividing the track into sections of varying length, according to local circumstances, and placing at one end of each section a battery having its poles connected one to each rail, and at the other end of each section a relay connected in like manner, one pole to each rail. Such a signal is set to "danger," either by shunting the circuit across the rails by the wheels and axles of a train, or by opening the circuit, as when a switch is thrown off the main line, or a rail is broken. The rails, on account of their contact with the ties and with the ground, allow a considerable leakage of the electric current from one rail to the other without passing through the relay, and this portion of the current has no useful effect. The amount of this leakage depends on the *insulation resistance*, and varies with the state of the weather and the condition of the track, etc.; but the insulation resistance of a section of railroad track is always comparatively low. A circuit of normal length, which has on a dry day an insulation resistance of say 5 ohms, may have on a wet day a resistance of not more than $2\frac{1}{2}$ ohms, a difference of 50 per cent. The leakage from one rail to the other is a shunt on the circuit through the relay. Suppose the resistance of the relay to be 9 ohms (about an average value), and the resistance of the line of rails to be 1.2 ohms, and the insulation resistance to be 5 ohms, then the whole resistance external to the battery is $\frac{9 \times 5}{9+5} + 1.2$, or 4.4 ohms; on a wet day the same circuit may have an insulation resistance of only $2\frac{1}{2}$ ohms; the total resistance will then be $\frac{9 \times 2.5}{9+2.5} + 1.2$, or 3.2 ohms. This change in the insulation resistance will materially alter the amount of current flowing through the relay, as this depends on the difference of potential or pressure between the terminals of the coils; and as this difference of pressure depends on the electro-motive force of the battery, and on the ratio between the resistance of the battery and that of the external

[1] Abstract of thesis in Electrical Engineering.

circuit, it becomes a matter of importance that this should be as uniform as possible, since a uniform current through the coils of the relay will give a constant pull on the armature of the magnet. This will also be affected by the relation between the total resistance and that of the relay magnet; hence this last should be properly proportioned to the circuit in which it is to be used.

For the successful working of signals by means of rail circuits, it is necessary that the electro-motive force of the battery employed should be low, in order that the leakage from rail to rail should not be large. Hence only a few cells can be used on one rail circuit. On some circuits it is necessary to use a relay of much less than the usual resistance, and occasionally to connect the cells in parallel, instead of in series, as is commonly done. In order to give the best results it is necessary to deal with each circuit by itself, and adapt the battery and relay to the particular circuit in which they are to be used. Often the relations of the different quantities must be determined by experiment, and cannot be decided beforehand. Where the rails are always wet (as, for example, in a tunnel), and where the leakage is usually excessive if the battery is connected in the ordinary manner, better results will be obtained by connecting the cells in parallel; that is, all the coppers together for a copper pole, and all the zincs together for a zinc pole. On the other hand, if the circuit be a long and dry one, the best effect will be obtained by connecting the cells in series. In very long circuits it is sometimes necessary to divide the rail circuit into two or more sub-circuits, with a battery and relay for each.

Following are some tables of measurements which have been made of the resistances of rail circuits. The resistance has been measured both in dry and wet weather in some cases. To get the variation, some circuits have been measured when short-circuited by trains in the section, and also with the relay open. The latter gives the resistance of the rails plus that of the insulation. The resistance of these circuits was also taken when they were all clear. This gives the resistance of the rails plus that of the relay as shunted by the leak. The resistance of the rails themselves has been found to vary from about eight tenths of an ohm, in short overlap blocks, to one and six tenths of an ohm on long sections containing switches. This includes the resistance of the underground wiring at the battery end of the section. The insulation resistance of the blocks has varied from two and five tenths ohms, to one hundred and forty ohms.

TABLE NO. I.

BOSTON AND ALBANY RAILROAD. BOSTON TO RIVERSIDE.

RELAYS 9 OHMS.

Date. 1890.	Signal Number.	Cells of Battery in Series.		Rail Lengths in Block.		Length in Feet.		Resistance of circuit external to battery in normal condition.		Weather, and state of road-bed.
		Long Side.	Short Side.	Long Side.	Short Side.	Long Side.	Short Side.	Long Side.	Short Side.	
Feb. 26.	11	2	.....	.....	.....	.....	.....	4.40	.....	Fed through tracks No. 1 and No. 3, into single track at Huntington Ave.
"	12	.....	.....	.....	24 5	.....	735	.....	8.26	Not stated.
"	13	.....	.....	.....	32	.....	960	.....	5.48	" "
"	14	.....	.....	.....	23	.....	690	.....	10.68	" "
"	15	.....	.....	.....	34	.....	1,020	.....	6.45	" "
"	16	.....	.....	84	.....	2,520	.....	5.06	.....	" "
"	18	.....	.....	88	.....	2,640	.....	3.59	.....	" "
Mar. 17.	21	.....	.....	74	.....	2,220	.....	5.65	.....	Comparatively dry.
"	22	.....	.....	.....	35	.....	1,050	.....	6.95	" "
"	23	.....	.....	74	.....	2,220	.....	6.95	"	" "
"	24	.....	.....	.....	34	.....	1,020	.....	7.42	" "
"	25*	.....	.....	.....	.....	.....	.....	.....	.....	
"	27	.....	.....	.....	28	.....	840	.....	7.85	" "
"	28	.....	.....	83	.....	2,490	.....	6.80	.....	" "
"	30	.....	.....	146	.....	4,380	.....	6.45	.....	" "
"	31	.....	.....	108	.....	3,240	.....	4.55	.....	" "
Mar. 15.	"	.....	.....	"	.....	"	.....	3.35	.....	Rails wet; melting snow.
Apr. 12.	"	.....	.....	"	.....	"	.....	3.55	.....	Track dry; 4-ohm relay.
Mar. 15.	33	.....	.. ..	"	.....	"	.....	3.53	.....	Melting snow; quite wet.
"	37	.....	.....	.....	40	.....	1,200	.....	6.75	" " "
Mar. 26.	51	2	.....	161	.....	4,830	.....	4.65	.....	Fair day; ground damp from rains.
"	53	2	.....	"	.....	"	.....	2.75	.....	" " "
"	54	.....	1	.....	42	.....	1,260	.....	5.25	" " "

* No measurements recorded in Mr. Mann's notes.

TABLE NO. I. — *Continued.*

Date. 1890.	Signal Number.	Cells of Battery in Series.		Rail Lengths in Block.		Length in Feet.		Resistance of circuit external to battery in normal condition.		Weather, and state of road-bed.
		Long Side.	Short Side.	Long Side.	Short Side.	Long Side.	Short Side.	Long Side.	Short Side.	
Mar. 21.	55	2	.....	49	.....	1,470	.....	5.85	.....	Misty and showery; track wet.
Mar. 26.	"	2	1	.....	44	.....	1,320	.....	6.65	Fair day; ground damp from rains.
"	56	.....	1	.....	41	.....	1,230	.....	5.35	" " "
"	57	.....	1	.....	44	.....	1,320	.....	5.25	" " "
Mar. 21.	"	2	.....	108	.....	3,240	.....	4.53	.....	Misty and showery; track wet.
Mar. 26.	58	2	1	141	45	4,230	1,350	4.65	6.45	Fair day; ground damp from rains.
Mar. 21.	59	2	1	59	44	1,770	1,320	6.35	5.05	Misty and showery; ground wet.
"	60	.....	1	.....	46	.....	1,380	.....	5.7	" " "
Mar. 26.	"	2	.....	141	.....	4,230	.....	3.75	.....	Fair day; ground damp from rains.
Mar. 21.	61	.....	1	.....	34	.....	1,020	.....	5.3	Misty and showery; track wet.
Mar. 19.	"	2	.....	54	.....	1,620	.....	8.45	.....	Heavy snow storm; cold.
Mar. 21.	62	.....	2	.....	47	.....	1,410	.....	10.8	Misty and showery; ground wet.
Mar. 26.	"	2	.....	58	.....	1,740	.....	5.45	.....	Fair day; ground damp from rains.
Mar. 21.	63	.....	1	.....	36	.....	1,080	.....	6.0	Misty and showery; track wet.
Mar. 19.	"	2	.....	53	.....	1,590	.....	7.65	.....	Heavy snow storm; cold.
"	64	.....	1	.....	41	.....	1,230	.....	10.75	" " "
Mar. 21.	"	2	.....	48	.....	1,440	.....	9.55	.....	Misty and showery; track wet.
"	66	3	.....	161	.....	4,830	.....	3.05	.....	" " "
Mar. 19.	"	.....	1	.....	34	.....	1,020	.....	8.15	Heavy snow storm; cold.
"	67	.....	1	.....	36	.....	1,080	.....	8.25	" " "
Total.	.....	.....	.....	.....	.....	.....	.....	120.56	148.79	
Average.	.....	.....	.....	.....	.....	.....	.....	4.82	6.47	

TABLE NO. II.

PROVIDENCE DIVISION OLD COLONY RAILROAD, BETWEEN BOSTON AND HYDE PARK.

RELAYS 9 OR 10 OHMS.

Date. 1890.	Signal Number.	Cells of Battery in Series.		Rail Lengths in Block.		Length in Feet.		Resistance of circuit external to battery in normal condition when circuit was clear.		Weather, and state of road-bed.
		Long Side.	Short Side.	Long Side.	Short Side.	Long Side.	Short Side.	Long Side.	Short Side.	
Apr. 23.	303	2	.....	133	.....	3,990	.....	1.95	.....	Dry and dusty.
"	304	.....	2	.....	60	.....	1,800	.....	4.8	" " "
"	305	2	.....	.....	.....	.....	.....	3.75	.....	" " "
May 7.	305	.....	2	.....	.....	.....	.....	.....	3.8	Fair day; track damp from rain yesterday.
"	303	.....	.....	.....	.....	.....	.....	1.6	.....	" " "
Apr. 23.	308	.....	2	.....	.....	.....	.....	.....	3.65	Dry and dusty.
"	309	2	.....	.....	.....	.....	.....	3.75	.....	" " "
"	312	2	2	.....	.....	.....	.....	4.03	5.35	" " "
"	313	.....	2	.....	.....	.....	.....	.....	6.15	" " "
"	314	2	.....	.....	.....	.....	.....	4.75	.....	" " "
May 7.	337	2	.....	150	.....	4,500	.....	2.34	.....	Fair day; track damp from rain yesterday.
"	341	.....	2	.....	41	.....	1,230	.....	5.30	" " "
Total.	.....	.....	.....	.....	.....	.....	.....	22.17	29.05	
Average.	.....	.....	.....	.....	.....	.....	.....	3.17	4 84	

TABLE NO. III.

NEW YORK AND NEW ENGLAND RAILROAD BETWEEN BOSTON AND DUDLEY STREET.

RELAYS 9 AND 16 OHMS.

Date. 1890.	Signal Number.	Cells of Battery in Series.		Rail Lengths in Block.		Length in Feet.		Resistance of circuit external to battery in normal condition when circuit was clear.		Weather, and state of road-bed.
		Long Side.	Short Side.	Long Side.	Short Side.	Long Side.	Short Side.	Long Side.	Short Side.	
Apr. 30.	1	.....	.....	103	.....	3,090	.....	3.20	.....	Dry.
"	2	.....	.....	.....	.....	.....	.....	4.30	.....	Dry.
"	3	.....	.....	.....	.....	.....	.....	Varied from 4.8 to 3.3	Varied from 5.7 to 5.0	Dry.
"	4	.....	.....	.....	.....	.....	.....	.....	3.73	A 10-ohm and a 16-ohm relay shunted on leak.
"	5	.....	.....	.....	.....	.....	.....	.....	8.54	Dry; one relay on circuit.
"	5	.....	.....	.....	.....	.....	.....	.....	5.76	Dry; two relays shunted on circuit.
"	6	.....	.....	.....	.....	.....	.....	8.43	.....	Dry.

The average of twenty-five measurements on the Boston & Albany Railroad of long sections was 4.82 ohms, and the average of short sections was 6.47 ohms. The average of seven long sections on the Providence Division of the Old Colony Railroad was 3.17 ohms, and of six short sections, 4.84 ohms. In explanation of these low averages it should be said that many of the signals are in yards and other places where there is a considerable accumulation of cinders on the track.

The insulation resistance of any block given in the tables may be found by subtracting the rail resistance from the quantity that is given under the proper "side." The rail resistance varies from eight tenths of an ohm on short sides to one and five tenths ohms on long sides. One and two tenths ohms will be a fair average.

The whole resistance minus the rail resistance will give the resist-

ance of the divided circuit of the relay and insulation. This quantity is equal to the relay resistance multiplied by the insulation resistance and divided by the sum of the two. The relay resistance being known, that of the insulation is readily found. Below will be found the calculation of the insulation resistance of two blocks. The result in both cases is much below the average:

SIGNAL NO. 1, NEW YORK & NEW ENGLAND RAILROAD.

Resistance of the long side with the circuit broken at the relay	4.2 ohms.
Resistance of the rails and ground-wires	1.6 "
Insulation resistance (the difference of the two)	2.6 "
Length of the block	3,090 feet.

Insulation resistance per mile $= \frac{3090}{5280} \times 2.6 = 1.5$ ohms.

SIGNAL NO. 337, PROVIDENCE DIVISION OLD COLONY RAILROAD.

Resistance of circuit in normal condition . . . . . 2.3 ohms.
Resistance of circuit when short-circuited by a train at the relay end of the section was . . . . . 1.2 ohms.

$2.3 - 1.2 = 1.1$ ohms $= \frac{9\,S}{9 + S}$ where 9 is the resistance of the relay in ohms, and S is the insulation resistance. Solving this equation with respect to S, we have $9.9 = 7.9\,S$; or S, the insulation resistance $= 1.3$ ohms; hence the insulation resistance per mile is equal to $\frac{4500}{5280} \times 1.3$, or 1.1 ohms.

The resistance of the rails is about the same on all circuits when the connections are all in good order.

SIGNAL NO. 303, PROVIDENCE DIVISION OLD COLONY RAILROAD. (Long side.)

Block short-circuited by a train at the relay end . . . 1.1 ohms resistance.
Block short-circuited by a wire at the battery end . . . 0.58 " "

This gives the resistance through 7,980 feet of rails as 0.52 ohm, the difference of the two.

In these measurements there was a path for the current through the wheels and axles of the cars, through the relay, and through the leak. The resistance of the wheels and axles was apparently so small in relation to the resistance of the relay and of the leak in parallel that their effect in lowering the total resistance was neglected. For Signal No. 337 above mentioned, with the long side short-circuited by a train at the relay end, the resistance was 1.2 ohms. The total length of the rails included in the circuit (that is, twice the length of the block)

was 9,000 feet. The measurement (1.2 ohms) gives the resistance of the 9,000 feet of rails, and of the ground wires at the battery end of the section. The rails on this road are connected by two wires around the joints. On the New York & New England Railroad the rails are connected by but one wire around the joints.

Signal No. 1, short-circuited by a train at the relay end, had a resistance of 1.6 ohms.
Short-circuited by a wire at the battery end . . . . 0.6 "

There is then a resistance in the rails themselves of one ohm in about 6,180 feet.

Signal No. 3, short-circuited by a train at the relay end . . . . 1.6 ohms.
Short-circuited by a wire at the battery end . . . 0.6 "

The ground wires in each case were about 60 feet long. The resistances of 1.6 ohms are noted here, as they seem rather high in comparison with others, and especially with 1.2 ohms, as measured on the very long circuit of Signal No. 337, Providence Division Old Colony Railroad, noted above. In the cases of abnormally high resistance it is probable that there is a loose connection or other point of great resistance.

It will be noticed from Table III that the resistance of two signals varied at short intervals of time from (in one case) 5.7 ohms to 5.0 ohms; in the other case, from 4.8 ohms to 3.3 ohms. These variations occurred when trains passed through the block. They might have been caused by the movement of some loose connection during the passage of the train. The resistance was measured in each case with the block clear and the signal at "safety."

There would probably be a considerable increase in steadiness realized by the use of two wires at each joint instead of one. With one exception, where other causes influenced the result, no variation of resistance was noticed when two wires were used. The insulation resistance usually varies from about 2 to about 4 ohms, but in one case it was found to be only 0.53 ohm; but on this circuit there was a large amount of leakage. The average resistance of a long side is less than that of a short side. The contact points of the relays included in the circuit often make a considerable difference in the resistance; in one case removing these from the circuit lowered the resistance by 0.6 of an ohm in a total resistance of about 2 ohms.

On certain circuits it is found an advantage to connect the batteries (of which there are usually two cells on each track circuit) in parallel instead of in series, as is ordinarily done. This gives but half the electro-motive force, it is true, but largely increases the quantity, and in case of the breakage of a cell the current is not totally interrupted, as is the case when they are connected in series.

ROGERS LABORATORY OF PHYSICS,
June, 1891.

NOTE.

Mr. Mann writes me that the apparatus used in these measurements was a portable Wheatstone Bridge, tested in the laboratory of the Massachusetts Institute of Technology and found to be correct to one one-thousandth of an ohm. Accuracy was desired in the measurements only to one one-hundredth of an ohm, on account of the wide variation in measurements of the same piece of track at different times. Several readings of each measurement were, however, taken, and usually found not to vary even in the third place; but the second place only is shown in the records, it being desired that there should be no larger error in the tables as recorded than was probable in the bridge itself. The battery used was that belonging to the track circuit measured, and the bridge was so connected with it that the resistance to be measured formed one branch of the bridge. These measurements are very interesting as being, so far as I know, the first of their kind. I myself once tried to measure the resistance of a line of rails one fourth of a mile in length (in fact one of the very same which Mr. Mann has measured), but found it so small that, with the apparatus I had at command, I obtained no results on which I dared to rely. Such measurements as I did get, however, agreed tolerably well with those obtained by Mr. Mann. I made no attempt to measure the insulation resistance.

GEORGE W. BLODGETT,
Electrical Engineer, Boston & Albany Railroad.

Boston, October 21, 1891.

ON THE PROPERTIES OF HYDROGEN PEROXIDE SOLUTIONS.

By HENRY P. TALBOT, Assistant Professor of Analytical Chemistry, and HERBERT R. MOODY, S.B.

Received August 4, 1892.

The information to be found in the present literature of hydrogen peroxide regarding either the preparation of concentrated solutions of that reagent, or the properties of such solutions after their preparation, is meager and unsatisfactory.

Thenard,[1] the first to identify this chemically interesting substance, concentrated the dilute solutions which he obtained by evaporation *in vacuo* over sulphuric acid. He succeeded in attaining a high degree of concentration, but this method is not suitable for the treatment of large quantities of solution. Since Thenard's work, the most important contribution to this branch of the subject is that made by Hanriot.[2] He found that on partially freezing a solution of hydrogen peroxide the liquid remaining after the removal of the ice contained a larger proportion of peroxide than the original solution, and took advantage of this fact as a means of concentration. In this way he obtained solutions which would yield of themselves 70 to 80 times their own volume of oxygen upon complete decomposition.

Hanriot subsequently found[3] that dilute solutions of hydrogen peroxide could be concentrated by distillation at greatly reduced pressures without serious loss by decomposition; and in this way, under a pressure of 3 mm., he obtained a solution which would evolve 267 times its own volume of oxygen, and states that no appreciable decomposition takes place below 150 volumes.

The writers of the present article have had occasion to deal with commercial solutions, and to prepare from them concentrated solutions

[1] Annales de chimie et de physique [2] 10 (1818), 114, 335; 11 (1819), 85.
[2] Comptes rendus de l'Académie des Sciences, 100 (1885), 57.
[3] Comptes rendus de l'Académie des Sciences, 100 (1885), 172.

in considerable quantities. The facts here presented are those which have been observed during the progress of this work, which have a bearing upon the questions in hand.

The commercial solutions found on the market varied in strength from eighteen volumes to twenty-three volumes, if only those are included which were known to have been freshly prepared. Others were found which were as low as eight volumes.

Kingzett[1] has called attention to the variations in custom as regards the expression of the value of solutions of hydrogen peroxide. He states that a 15-volume solution is properly "one which of itself, by complete decomposition, will furnish fifteen times its own volume of oxygen at ordinary temperature and pressure;" but he points out that the American custom designates as a 15-volume solution one which will evolve fifteen times its own volume of that gas when brought into contact with a substance which itself furnishes one half the volume of oxygen. It is evident that the latter solution has but one half the strength of the former. Since the latter method of expression is that used commercially, it will be employed throughout this article; but attention is called to the fact that for purposes of oxidation the amount of available oxygen is but one half that indicated by the commercial name.

A suggestion made by Dr. F. H. Williams, that the strength of solutions should be uniformly expressed in percentage of hydrogen peroxide, is one which, if generally adopted, would avoid the confusion now existing, and would be more readily understood by physicians.[2]

In view of the fact that hydrogen peroxide is generally recommended as a useful reagent in analytical chemistry, it is desirable that something should be known regarding the purity of the solutions which are readily available. Of the eight commercial samples examined, none were suitable for analytical purposes without purification, and most were so impure that their use would be ill-advised even though blank analyses had been made. They contained hydrochloric, sulphuric, phosphoric and hydrofluosilicic acids, sugar and glycerine. The two latter substances were present in largest amounts in the

[1] Journal of the Society of Chemical Industry, 9 (1890), 4.

[2] It may be noted here, for purposes of comparison, that a 20-volume solution (as the term is used in this article), contains 2.9 per cent. of hydrogen peroxide; a 50-volume solution, 6.9 per cent., and a 100-volume solution, 13.4 per cent., by weight.

sample prepared for medicinal use. Barium, calcium, aluminum and magnesium were also found.

The amount of phosphoric acid, as found by precipitation with ammonium molybdate and reprecipitation as magnesiun ammonium phosphate, was in one sample 0.16 per cent., in another 0.13 per cent. of the solution by weight; an amount capable of doing much mischief in analytical work.

Fifty cubic centimeters of a commercial sample evaporated on a water bath left a residue weighing 0.0588 grm., of which 0.0418 grm. remained after ignition. This sample contained sulphuric, phosphoric and hydrofluosilicic acids and barium. A sample intended for medicinal use yielded a syrupy residue on evaporation, the amount from 50 cc. weighing 0.4400 grm.; at 130° C. it was still syrupy, but had the odor of caramel, and the weight had fallen to 0.4195 grm.; upon ignition over a Bunsen burner glycerine distilled, and the sugar was charred and burned, the residue, after treatment with ammonium nitrate, being white, and weighing 0.0164 grm. This residue was largely barium chloride.

The presence of hydrofluosilicic acid in these solutions is also a menace to analytical work since, upon subsequent neutralization of the acid, the precipitation of an insoluble hydrofluosilicate or of silicic acid takes place, either of which is likely to interfere with gravimetric processes. The amount of hydrofluosilicic acid found in one sample —a 22-volume solution— was 0.05 per cent. of the solution by weight. The acid was precipitated and weighed as potassium silicofluoride, and was also determined from the amount of silica present.

An order placed with one of the manufacturers for a preparation of hydrogen peroxide which should be sufficiently pure for analytical purposes resulted in the production of a solution which was free from phosphoric acid, and yielded but 0.0049 grm. of ignited residue from 50 cc. of the sample. The amount of silica found was 0.0026 per cent., and only minute quantities of calcium and aluminum, with a little organic matter, were present. This sample might have been used for analytical purposes without further purification.

As a method of purification of the commercial solutions, the following was found most successful. The solution was treated with about 10 per cent. by volume of alcohol, after which barium hydrate in powder was added to distinctly alkaline reaction. The precipitate, containing most of the impurities, was then filtered off with the help of a

gentle suction, using a porcelain filter plate, and the excess of barium removed by the addition of sulphuric acid in excess. The barium sulphate was allowed to settle, and the supernatant liquid quickly filtered as before. The loss of peroxide is small if the first filtration is hastened, thereby reducing the time during which the solution remains alkaline. By this method the amount of silica was reduced from 0.028 per cent. to 0.003 per cent. of the solution by weight. The alcohol may be removed by distillation at reduced pressure, and the residual solution may then be used for analytical purposes without further precaution than the customary blank analysis. The barium hydrate used should be as free from carbonate as possible.

It was subsequently found that a solution thus treated could be further purified by distillation, but only at a great sacrifice of material. This will be referred to again.

The addition of ferric chloride and subsequent precipitation with barium hydrate cannot be employed as a means of purification, since the formation of ferric hydrate in the solution causes prompt and complete decomposition of the peroxide which the previous addition of alcohol, ether, or their mixture, does not hinder.

It was found that the concentrated solutions containing phosphoric and hydrofluosilicic acids, when shaken with ether, gave up a portion of these acids together with the peroxide. Purification by this means, therefore, was not possible. Experiments proved that for practical purposes concentration by distillation at reduced pressure is preferable to freezing. The distillations were made in glass — an ordinary round-bottomed flask or a boiling flask, a Liebig condenser and glass receiver comprising the apparatus. The stoppers were of rubber. For distillations at pressures less than that of the atmosphere the apparatus was connected with a suction pump capable of reducing the pressure to 30 or 40 mm. To prevent violent bumping, it was usually necessary to insert a capillary tube and draw a slow current of air through the solution in the boiling flask. This bumping is, in itself, an evidence that the decomposition of the peroxide is slight. To prevent decomposition by over-heating, the flask was placed in a water bath.

The rate at which the solutions concentrate under varying conditions may be learned from the tables below. The column marked "Per cent. total loss" expresses the percentage of hydrogen peroxide which the solution has lost during the distillation, and is calculated upon the theoretical concentration, which, in turn, is estimated from

the decrease in volume of the solution in the boiling flask, and takes no account of the small quantity of peroxide which passes into the distillate. The commercial solution employed was a 20-volume solution, containing as impurities, phosphoric, hydrofluosilicic, sulphuric and hydrochloric acids, and a small quantity of iron.

The rate of concentration of the residual solution in the boiling flask was determined by titration with potassium permanganate. One cubic centimeter was removed with a pipette, diluted with fifty to seventy-five cubic centimeters of distilled water, acidified with sulphuric acid, and titrated to the customary end point. This was the method employed in all determinations mentioned, and a comparison of this method with a gas-volumetric process will be made at the close of the article.

CONCENTRATION BY DISTILLATION.

I. AT ATMOSPHERIC PRESSURE.				II. UNDER PRESSURE OF 390 mm.			
Volume of Distillate.	Strength of Distillate.	Strength of Residual Solution.	Per cent. Total loss.	Volume of Distillate.	Strength of Distillate.	Strength of Residual Solution.	Per cent. Total loss.
65 cc.	0.6 vols.	16.5 vols.	30.6	50 cc.	0.6 vols.	22.9 vols.	0.0
65 cc.	0.6 "	20.9 "	29.3	60 cc.	0.8 "	26.2 "	4.7
65 cc.	0.5 "	21.2 "	45.6	50 cc.	0.6 "	30.2 "	9.3
65 cc.	0.6 "	26.5 "	53.5	50 cc.	0.5 "	38.5 "	8.4
65 cc.	0.8 "	32.5 "	69.5	50 cc.	0.8 "	42.2 "	26.0
50 cc.	2.24 "	81.0 "	70.4	50 cc.	0.8 "	52.8 "	40.5
.....	.....	.....	.....	40 cc.	2.0 "	73.1 "	54.3
.....	.....	.....	.....	20 cc.	1.1 "	84.0 "	68.4

Original volume = 400 cc.
Original strength = 20 vols.

CONCENTRATION BY DISTILLATION.

III. UNDER PRESSURE OF 140 mm.				IV. UNDER PRESSURE OF 30 mm.			
Volume of Distillate.	Strength of Distillate.	Strength of Residual Solution.	Per cent. Total loss.	Volume of Distillate.	Strength of Distillate.	Strength of Residual Solution.	Per cent. Total loss.
55 cc.	0.5 vols.	23.1 vols.	0.0	50 cc.	0.9 vols.	22.0 vols.	2.7
55 cc.	0.8 "	26.8 "	0.8	50 cc.	0.9 "	25.2 "	5.0
55 cc.	0.8 "	30.8 "	9.4	50 cc.	0.9 "	29.6 "	6.9
55 cc.	0.8 "	39 0 "	12.1	50 cc.	0.9 "	37.8 "	5.5
65 cc.	1.2 "	63.6 "	8.4	50 cc.	0.9 "	49.8 "	7.7
60 cc.	2.0 "	138.7 "	4.6	50 cc.	1.3 "	77.2 "	2.7
20 cc.	6.3 "	189.4 "	7.0	50 cc.	9.4 "	151.2 "	4.8

Original volume = 400 cc.
Original strength = 20 vols.

Original volume = 400 cc.
Original strength = 19.84 vols.

CONCENTRATION BY DISTILLATION.

V. AT ATMOSPHERIC PRESSURE WITH THE ADDITION OF PHOSPHORIC ACID.				VI. AT 390 mm. PRESSURE WITH THE ADDITION OF PHOSPHORIC ACID.			
Volume of Distillate.	Strength of Distillate.	Strength of Residual Solution.	Per cent. Total loss.	Volume of Distillate.	Strength of Distillate.	Strength of Residual Solution.	Per cent Total loss.
60 cc.	0.6 vols.	21.1 vols.	10.8	40 cc.	0.6 vols.	21.5 vols.	4.0
60 cc.	0.7 "	24.5 "	15.0	50 cc.	0.6 "	22.3 "	13.9
60 cc.	0.8 "	27.9 "	23.5	50 cc.	0.9 "	26 5 "	14.2
60 cc.	0.8 "	35.6 "	29.2	50 cc.	1.3 "	31.5 "	18.0
65 cc.	1.9 "	54.2 "	35.9	50 cc.	0.9 "	37.8 "	24.7
60 cc.	3.1 "	69.0 "	70.0	60 cc.	1.9 "	53.9 "	32.9
25 cc.	8.5 "	0.3 "	99.9	50 cc.	4.1 "	107.3 "	33.2
.....	.....	.....	.....	45 cc.	19.2 "	6.3 "	99.8

Original volume = 400 cc.
Original strength = 20.2 vols.

It is obvious that the figures representing the loss by decomposition in these tables must be approximate only, since this is influenced by the amount of mechanical agitation of the solution and the length of time which it has stood at the temperature of the laboratory previous to distillation. Another factor which influenced the results when the distillation was made at very low pressure, was the removal of uncondensed steam through the suction pump, the low temperature at which the solution boils (36° C. for 30 mm. pressure), making it difficult to effect complete condensation. Tables I to IV, inclusive, show approximately the rate of concentration under varying conditions, and demonstrate the fact that strong solutions may be prepared by distillation at a pressure of 30 to 40 mm. without serious loss. The addition of certain non-volatile substances as preservatives during distillation was not attended with a large degree of success. Sulphuric acid, boracic acid, phosphoric acid and glycerine were each tried; but of these phosphoric acid alone appeared to hinder decomposition, and that only within certain limits, as shown by Tables V and VI. At the lower pressure the results are more favorable than in the absence of the acid, until the solution is highly concentrated. Ten cubic centimeters of a saturated solution of phosphoric acid were used in the first case (Table V), and five cubic centimeters in the second. Of the action of the remaining acids and glycerine it may be said that they appear to hinder decomposition only at the first, after which they increase rather than lessen the loss. It may be mentioned that the presence of an excess of caustic alkali or ammonia causes prompt and complete decomposition of the peroxide.

The figures given in Tables III and IV show that appreciable quantities of hydrogen peroxide pass into the distillates as the solution in the boiling flask concentrates. This fact may be utilized as a method of purification of the peroxide solutions from most of the foreign ingredients. It is not wholly successful, since the hydrofluosilicic acid is present in such large quantities that, at the point at which the peroxide begins to pass over in any considerable quantity, this acid is decomposed and silicon fluoride passes into the distillate with the re-formation of hydrofluosilicic acid. This was made evident by the accumulation of silicic acid in the condenser from the partial decomposition of the silicon fluoride by condensed steam. The distillate is free from other impurities than the hydrofluosilicic acid, and by a second concentration a very pure solution could doubtless be obtained, but at a great sacrifice of material. By subjecting the fil-

trate from the precipitation with barium hydrate in the presence of alcohol, as already described, to distillation at reduced pressure, it is easy to obtain a distillate which, while weak, contains but a minute quantity of hydrofluosilicic acid. It may be concentrated after the addition of such a quantity of sulphuric acid that, when concentrated to a 20-volume solution, it shall contain about 0.2 per cent. by weight of the acid.

The statement is made by Hanriot[1] that pure hydrogen peroxide gives an acid reaction; but distillates prepared as just described, capable of evolving nine volumes of oxygen, are but very feebly acid (which may be accounted for by the presence of hydrofluosilicic acid and hydrofluoric acid in very small quantities), and when made neutral by a drop of an alkali solution remain so, even though the amount of peroxide is undiminished. It appears to us that the statement of Hanriot cannot be correct, although he claims to have proved the absence of acid in the solutions tested.

The data already presented make it evident that the preparation of concentrated solutions of hydrogen peroxide from the commercial solutions is a matter of but little difficulty, unless the complete absence of foreign matter is required. The writers have prepared considerable quantities of solutions, varying in strength from thirty to five hundred and eighty-eight volumes. It has generally been found expedient to concentrate the solution to about fifty volumes before making any attempt to purify, unless the purification is accomplished by precipitation with barium hydrate, in which case the precipitation must precede the concentration. A convenient procedure by which the impurities may be largely removed is the following: The solution is made neutral with caustic potash (as free from carbonate as possible), and the precipitate of silica, potassium silicofluoride and other impurities is allowed to settle. This takes place promptly. The supernatant liquid is then decanted through a ribbed filter, and the last portion, which contains the precipitate, and therefore filters slowly, is rejected, or preserved for re-concentration if necessary. In this way a solution is obtained which is free from most of the original impurities, but contains potassium salts of the acids present. The filtered liquid should be made acid with sulphuric acid as soon as filtered, to prevent the decomposition of the peroxide in neutral solution, and the

[1] Comptes rendus de l'Académie des Sciences, 100 (1885), 172.

amount of acid added to a 50-volume solution should be about 0.5 per cent. by weight. An equivalent amount of hydrochloric acid may be substituted for the sulphuric acid.

In the preparation of solutions above fifty or sixty volumes it is expedient to purify with caustic potash, if this is the method used, before concentrating beyond this point, since the stronger solutions decompose with great rapidity as soon as the acid is neutralized.

The loss of strength is very gradual even in highly concentrated solutions, provided there is free acid present. The accompanying table will furnish data in support of this statement.

STABILITY OF CONCENTRATED SOLUTIONS.

No.	Nature of Solution.	Acidity in terms of H_2SO_4.	Original Strength.	Time of Standing.	Temperature.	Final Strength.	Per cent. loss.
1.	Commercial solution.	Approx. 0.2 per cent.	19.4 vols.	3 days.	70° to 80° F.	19.4 vols.	0 0
		.....	.....	7 "	" "	19.2 "	1.0
		.....	.....	13 "	" "	19 2 "	1.0
2.	Commercial solution concentrated at reduced pressure.	Approx. 0.5 per cent.	44.6 vols.	3 days.	70° to 80° F.	44.6 vols.	0.0
		.....	.....	7 "	" "	43.5 "	2.4
		.....	.....	13 "	" "	43.0 "	3.6
		.....	.....	42 "	" "	40.4 "	9.4
		.....	.....	128 "	" "	27.9 "	37.4
3.	Commercial solution concentrated and purified by KOH.	Sufficiently acid to reddened litmus.	41 vols.	2 days.	70° to 80° F.	41.2 vols.	0.0
		.....	.....	29 "	" "	32.0 "	22.3
		.....	.....	115 "	" "	11.9 "	71.4
4.	Commercial solution concentrated and purified by KOH.	Nearly neutral.	47.5 vols.	2 days.	70° to 80° F.	42.1 vols.	11.3
		.....	.....	22 "	" "	7.0 "	85.2
		.....	.....	110 "	" "	0.5 "	98.9
5.	Commercial solution concentrated at reduced pressure.	0.9 per cent.	99.4 vols.	3 days.	70° to 80° F.	100 3 vols. (?)	0.0
		.....	.....	17 "	" "	82.7 "	16.8
		.....	.....	24 "	" "	76.0 "	23.4
6.	Commercial solution concentrated at reduced pressure.	1.9 per cent.	202 vols.	3 days.	70° to 80° F.	188.0 vols.	6.9
		.....	.....	14 "	" "	130.0 "	35 6
		.....	.....	21 "	" "	105.0 "	48.0
		.....	.....	86 "	" "	22 8 "	88.2
7.	Commercial solution concentrated.	Alkaline with KOH.	34.4 vols.	2 days.	70° to 80° F.	9.10 vols.	73 5
		.....	.....	8 "	" "	1.8 "	94 8
8.	Commercial solution concentrated.	Alkaline with NH_4OH.	28.9 vols.	2 days.	70° to 80° F.	0.6 vols.	97.9
		.....	.....	8 "	" "	0.0 "	100.0

STABILITY OF CONCENTRATED SOLUTIONS.

No.	Nature of Solution.	Acidity in terms of H_2SO_4.	Original Strength.	Time of Standing.	Temperature.	Final Strength.	Per cent. loss.
9.	Commercial solution concentrated at reduced pressure.	3.7 per cent.	390 vols.	13 days.	32° F.	336 vols.	13.8
		.....	.....	19 "	"	332 "	14.8
		.....	.....	30 "	"	310 "	20.5
		.....	.....	37 "	"	290 "	25.6
10.	Commercial solution concentrated at reduced pressure.	2.9 per cent.	300 vols.	9 days.	32° F.	274.0 vols.	8.6
		.....	.....	15 "	"	271.4 "	9.5
		.....	.....	26 "	"	250.8 "	16.4
		.....	.....	33 "	"	240 0 "	20.0
11.	Prepared from No. 10 by dilution.	1.9 per cent.	202 vols.	3 days.	32° F.	201.6 vols.	0.1
		.....	.....	6 "	"	194.0 "	3.9
		.....	.....	17 "	"	180 6 "	10 0
		.....	.....	24 "	"	169.7 "	16.0
12.	Prepared from No. 10 by dilution.	0.9 per cent.	100 vols.	3 days.	32° F.	99.4 vols.	0.6
		.....	.....	6 "	"	98.6 "	1.4
		.....	.....	17 "	"	96.1 "	3.9
		.....	.....	24 "	"	95.0 "	5.0

A comparison of the solutions numbered 2 to 8, inclusive, shows that those which have been prepared by the evaporation of commercial solutions, without neutralization, maintain their strength for a considerable length of time; while those which have been made neutral decompose in a few days, and an excess of alkali causes immediate deterioration. In some cases the decomposition upon the addition of the alkali was spontaneous and accompanied by a marked evolution of heat. Solutions which have been even partially neutralized by alkali carbonates deteriorate during the neutralization, the carbonic acid evolved acting mechanically to destroy the peroxide.

It is also evident from the foregoing table that solutions of less strength than 100 volumes may be kept for some time at the temperature of the laboratory; but an examination of solutions 9 to 12, inclusive, shows that the highly concentrated solutions are preserved for much longer periods if kept at low temperatures. The stronger solutions — from 50 to 400 volumes — find their chief use in medicine and dentistry, and a loss of 10 per cent. in strength does not interfere with their practical efficiency. A glance at the table shows that, even in the case of the strongest solution, several days elapse before the value of the solution diminishes to that extent. It should be mentioned that these solutions were stoppered, and were only disturbed when the samples were removed for analysis. The deterioration would have been slightly greater if the solutions had been frequently exposed to the air or frequently shaken; but the fact is demonstrated that, if reasonable precautions are taken, even 400-volume solutions, if freshly prepared, may be preserved sufficiently long to admit of their practical use by physicians in extreme cases. They should be carefully stoppered, kept at a low temperature, out of contact with daylight, and should be disturbed as little as possible. To what extent the permanency of the strong solution may be increased by the addition of the preservatives recommended by Kingzett for commercial solutions, the writers have not yet determined.

Finally, a few words regarding the practical value of the permanganate method for the determination of the amount of the hydrogen peroxide present. If, as has been stated, the oxygen evolved during the treatment with permanganate is not furnished equally by that reagent and the hydrogen peroxide, the titration should not yield accurate results. For the purpose of comparison, the amount of oxygen evolved by the solution alone was determined with the aid of the

following apparatus: A boiling flask, of 30 cc. capacity, was connected at its neck, by means of a T tube, with a carbonic acid generator, and with a 2 cc. pipette. The delivery tube from the boiling flask was connected with a Mitscherlich bulb surrounded by ice, and that, in turn, with an azotometer filled with a caustic potash solution (sp. gr. 1.27). The air was first expelled from the apparatus by a current of carbonic acid, after which the stopper of the flask was removed to insert the hydrogen peroxide (2 cc.), and the small quantity of air introduced was again removed. The introduction of the peroxide was delayed until the greater portion of the air had been expelled, to prevent possible decomposition due to the contact with the carbonic acid for a longer time. Finally, 2 cc. of a solution of caustic potash (sp. gr. 1.27) was admitted through the pipette and T tube, which caused immediate evolution of oxygen. A gentle pressure of carbonic acid was maintained, and the flask heated in an oil bath until the solution had completely evaporated. The Mitscherlich bulb acted as a condenser, but no trace of undecomposed peroxide could be found in the condensed liquid. The oxygen passed into the azotometer and was measured, transferred to a Hempel pipette, the oxygen absorbed in potassium pyrogallate and the small amount of air deducted. The residual volume was corrected for temperature and pressure. The results were as follows:

A solution which, from the titration with potassium permanganate, should evolve 10.08 volumes of oxygen at 0° and 760 mm., was found, by the gas-volumetric method just described, to evolve 10.12 and 10.22 volumes (corrected), the variation being 0.4 and 1.4 per cent. respectively; showing that for practical purposes the results obtained by titration with a solution of potassium permanganate, which has been standardized against iron wire, are sufficiently accurate. No further comparisons have yet been made of this gas-volumetric method with other methods; but the apparatus is so easily constructed, and the process is so simple and rapid, that it commends itself as a ready means for the determination of the amount of oxygen which the peroxide solution alone will furnish.

In conclusion, the writers desire to express their indebtedness to Dr. T. M. Drown for valuable suggestions and kind interest throughout the work.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
July, 1892.

THE VOLATILITY OF STANNIC CHLORIDE.

By THOMAS M. DROWN and GEORGE F. ELDRIDGE.

Received August 20, 1892.

It is well known that there is a loss of tin in evaporating solutions of stannic chloride; but the amount of tin thus lost, under different conditions of dilution, temperature and acidity, seems not to have been hitherto determined. Owing to our lack of knowledge on this subject we have not dared to evaporate even very dilute solutions of stannic chloride in cases where the amount of tin was to be determined, nor have we known whether tin could be completely volatilized as stannic chloride when associated with other metals. The following investigation was undertaken to ascertain some facts with regard to the volatility of stannic chloride.

It is not an easy matter to determine directly the amount of tin lost on evaporation on account of the difficulty of condensing completely the vapors of stannic chloride. For this reason the amount of tin volatilized was in all cases determined by loss.

As the work planned involved more than a thousand determinations of tin, it was necessary to have an accurate and rapid volumetric method for this purpose. The following method we found left nothing to be desired, both as regards accuracy and rapidity. To a small bulk of tin solution, say 5 cc., is added from two to three tenths of a gram of powdered zinc,[1] which reduces the tin practically instantaneously to the metallic state. Forty cubic centimeters of hydrochloric acid of 1.2 sp. gr. are then added, which dissolves the finely divided metallic tin within a minute. A solution of ferric chloride is now added in slight excess, and the amount of ferrous chloride formed in the reaction with the stannous chloride is determined by titration with potassium bichromate, using potassium ferricyanide as an indicator.

[1] The powdered zinc is made by shaking melted zinc in a closed vessel near the point of solidification. It is then sifted to obtain a powder of uniform grain. That used in these experiments passes through a sieve of sixty meshes to the linear inch.

The following determinations, made by dissolving pure tin in hydrochloric and oxidizing to the stannic condition, show the limits of accuracy of the process:

	Tin taken. Gram.	Tin determined. Gram.
1	0.8542	0.8549
2	0.1724	0.1702
3	0.5638	0.5630
4	0.0922	0.0932
5	0.1749	0.1742
6	0.2348	0.2357
7	0.0124	0.0129
8	0.7721	0.7708
9	0.2432	0.2435
10	0.4651	0.4664

It was found that it made no difference whether the ferric chloride was added to the hot or cold solution of stannous chloride, and also that the solution of the stannous chloride could stand at least five hours (before the addition of the ferric chloride and the titration with potassium bichromate) without noticeable change.

The stannic chloride used in these experiments was made by dissolving pure tin in hydrochloric acid and oxidizing by chlorine gas. The chlorine and the greater part of the excess of hydrochloric acid were driven off by evaporation, and the semi-solid residue of stannic chloride dissolved in water. Ten cubic centimeters of this solution were taken in the various experiments, and diluted to exactly twenty cubic centimeters with water or acid, according to the object of the experiment. This amount of solution was placed in a round-bottomed flask of 200 cc. capacity, which was immersed to its neck in a bath of high-boiling petroleum oil. The amount of tin volatilized at different temperatures and during different times was determined by taking a sample from the stannic chloride remaining in the flask. There was undoubtedly some stannic chloride condensed in the neck which flowed back into the flask, so that the losses as determined

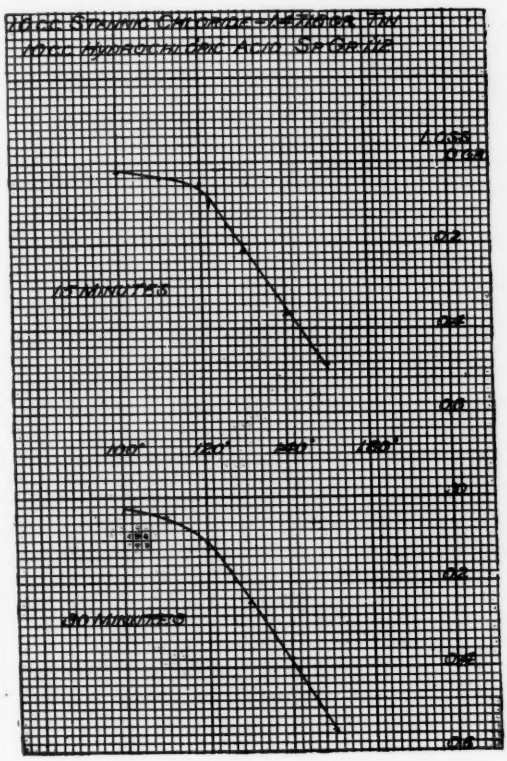
by this method are somewhat lower than would be the case in open dishes, or if the flask had been immersed in the oil bath to the top of the neck.

The evaporations at the different temperatures were all made in duplicate, and four determinations were made of the tin remaining in the flasks in all cases. In the first series of evaporations in flasks a more concentrated solution of stannic chloride was used than in the subsequent experiments. The results of this series are as follows:

10 cc. stannic chloride containing 1.4716 grams tin and 10 cc. hydrochloric acid (sp. gr. 1.12).

Temperature. Centigrade degrees.	Time. Minutes.	Loss of Tin. Gram.
100	15	0.0206
100	30	0.0354
110	15	0.0445
110	30	0.0484
120	15	0.0546
120	30	0.1025
130	15	0.2185
130	30	0.2523
140	15	0.3069
140	30	0.3795
150	15	0.4835
150	30	0.5328

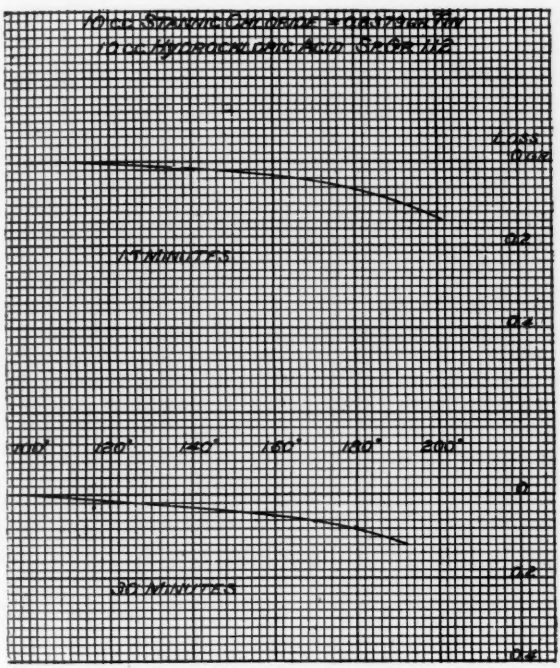
These results show that an acid, concentrated solution of stannic chloride cannot be heated fifteen minutes to 100° without the loss of an appreciable amount of tin, and that at higher temperatures the loss is very rapid. The results of this series are shown graphically in the following diagram :



A solution of stannic chloride containing less than half the amount of tin used in the previous experiment was next tried under the same conditions. The results were as follows:

10 cc. stannic chloride containing 0.6379 gram tin and 10 cc. hydrochloric acid (sp. gr. 1.12).

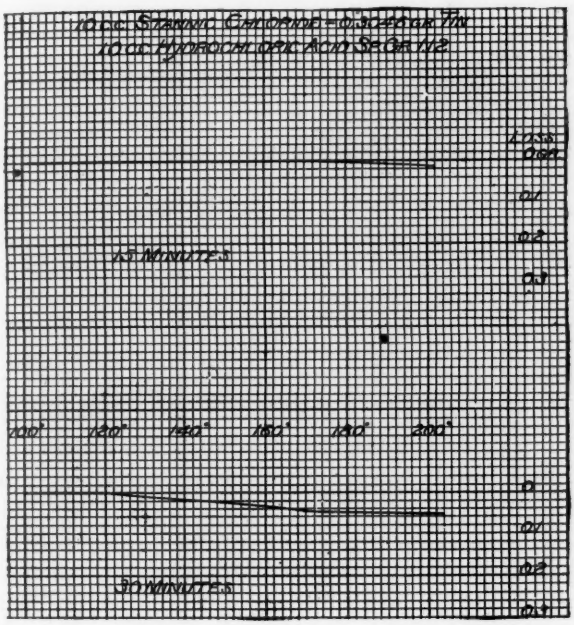
Temperature. Centigrade.	Time. Minutes.	Loss of Tin. Gram.
100	15	None.
100	30	None.
110	15	None.
110	30	0.0084
120	15	0.0042
120	30	0.0162
130	15	0.0108
130	30	0.0240
140	15	0.0180
140	30	0.0310
150	15	0.0222
150	30	0.0389
160	15	0.0346
160	30	0.0506
170	15	0.0465
170	30	0.0638
180	15	0.0619
180	30	0.0750
190	15	0.0935
190	30	0.1143
200	15	0.1310
200	30	Decomposed.



These results point to the fact that a certain concentration must be reached before any tin is volatilized from its solutions. The greater volatility of the more concentrated solution is well shown in comparing the two diagrams. A still more dilute solution of tin was used in the next experiment.

10 cc. stannic chloride containing 0.3046 gram tin and 10 cc. hydrochloric acid (sp. gr. 1.12).

Temperature. Centigrade.	Time. Minutes.	Loss of Tin. Gram.
100	15	None.
100	30	None.
110	15	None.
110	30	None.
120	15	None.
120	30	None.
130	15	None.
130	30	0.0125
140	15	None.
140	30	0.0167
150	15	None.
150	30	0.0232
160	15	None.
160	30	0.0333
170	15	None.
170	30	0.0475
180	15	0.0041
180	30	0.0493
190	15	0.0071
190	30	0.0482
200	15	0.0131
200	30	0.0487

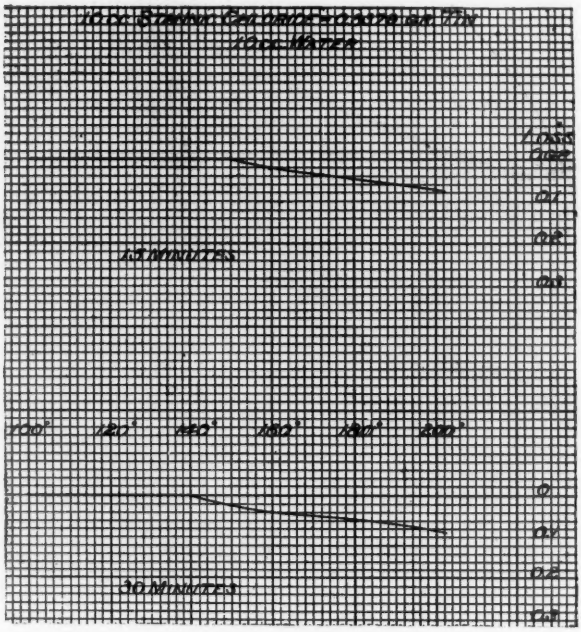


These results confirm those of the previous series, that dilute solutions of stannic chloride may be heated for some time without loss of tin.

To determine the effect of the amount of free acid on the volatility of the tin a solution was prepared, in which the 10 cc. of acid were replaced by 10 cc. of water.

10 cc. stannic chloride containing 0.6379 gram tin and 10 cc. water.

Temperature. Centigrade.	Time. Minutes.	Loss of Tin. Gram.
150	15	None.
150	30	0.0232
160	15	0.0268
160	30	0.0398
170	15	0.0298
170	30	0.0470
180	15	0.0516
180	30	0.0584
190	15	0.0595
190	30	0.0681
200	15	0.0748
200	30	0.0840

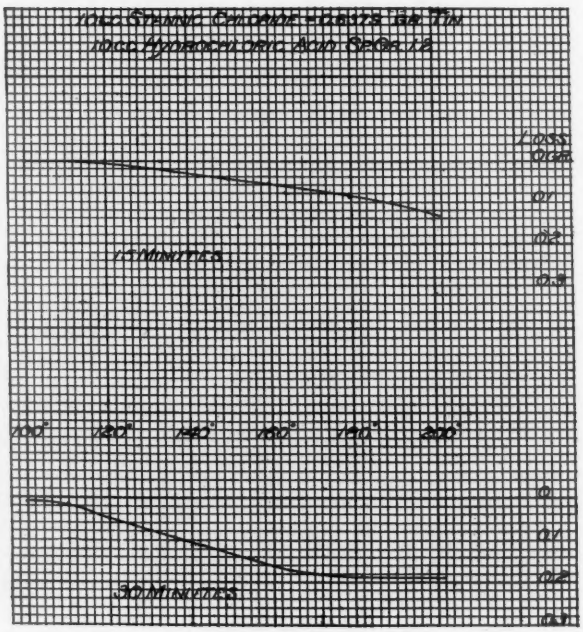


This series is comparable with the second series in amount of tin, and it will be noticed that whereas in this series no loss of tin occurs until the solution is heated to 150° for thirty minutes, in the series containing the free hydrochloric acid a notable loss occurred when the solution was heated for thirty minutes to 110°.

In all the experiments there was observed a decomposition of the stannic chloride with the formation of a non-volatile hydrate of tin when a certain concentration was reached. In the case of the acid solution (second series) this decomposition began at 180°; in the last series, in which the acid was replaced by water, the decomposition began at 160°. The presence of free hydrochloric acid is thus shown to be favorable to the volatilization of tin, both at low and at high temperatures. In the next series the same amount of tin was used, but a stronger hydrochloric acid.

10 cc. stannic chloride containing 0.6379 gram tin and 10 cc. hydrochloric acid (sp. gr. 1.2).

Temperature. Centigrade.	Time. Minutes.	Loss of Tin. Gram.
100	15	None.
100	30	0.0132
110	15	None.
110	30	0.0150
120	15	0.0071
120	30	0.0489
130	15	0.0191
130	30	0.0941
140	15	0.0335
140	30	0.1065
150	15	0.0489
150	30	0.1136
160	15	0.0554
160	30	0.1607
170	15	0.0739
170	30	0.1798
180	15	0.0881
180	30	0.1875
190	15	0.0995
190	30	0.1864
200	15	0.1346
200	30	0.1893

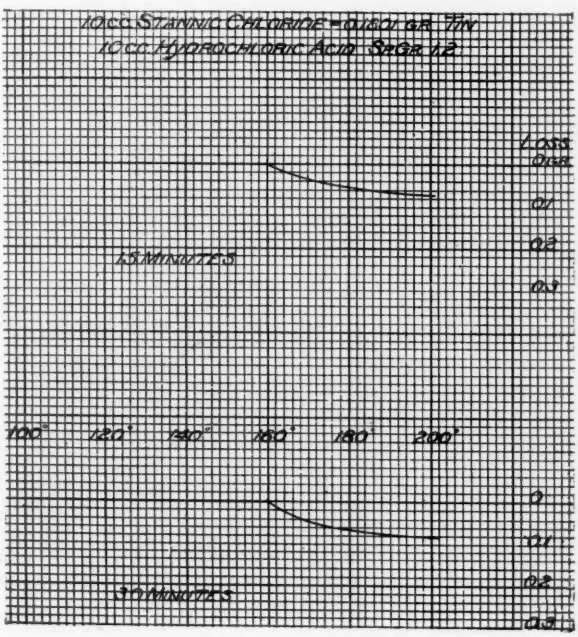


These results confirm those of the previous series in showing the favorable influence of hydrochloric acid on the volatilization of the tin. It will also be noticed in this series that at the three highest temperatures, namely, 180°, 190° and 200°, the loss in thirty minutes is practically the same. At 180° the solution goes to dryness in thirty minutes, and the tin being then in the form of hydrate, no further volatilization is possible. The same result took place with the more dilute solution of tin (as shown in the third series of experiments) at a temperature of 170°.

The next series of experiments was made to determine the effect of strong hydrochloric acid on very dilute solutions of tin. A few cubic centimeters of the solution used in the previous series were diluted with hydrochloric (sp. gr. 1.2) to 10 cc., and 10 cc. additional of hydrochloric acid added.

10 cc. stannic chloride containing 0.1801 gram tin and 10 cc. hydrochloric acid (sp. gr. 1.2).

Temperature. Centigrade.	Time. Minutes.	Loss of Tin. Gram.
160	15	None.
160	30	None.
170	15	0.0366
170	30	0.0445
180	15	0.0525
180	30	0 0617
190	15	0.0638
190	30	0.0750
200	15	0.0710
200	30	0.0823



There is thus shown to be no loss of tin in this dilution until a temperature of 170° is reached, notwithstanding the large amount of free acid present. A certain concentration of the stannic chloride is necessary before volatilization can occur.

It has already been mentioned that there is no further loss of tin after the chloride is decomposed and the hydrate formed. An attempt was made to determine the point at which a solution of stannic chloride begins to decompose at different temperatures. A series of flasks containing the same amount of stannic chloride and hydrochloric acid were heated in oil baths at different temperatures, and the time noted when the solutions showed by their turbidity that the hydrate was beginning to form. The amount of tin lost during these periods was then determined.

10 cc. stannic chloride and 10 cc. hydrochloric acid (sp. gr. 1.2).

Temperature. Centigrade.	Time. Minutes.	Loss of Tin. Gram.
100	270	0.0814
110	225	0.0760
120	120	0.0840
130	90	0.0768
140	60	0.0786
150	45	0.0846
160	40	0.0780
170	28	0.0734
180	25	0.0886
190	18	0.0847
200	15	0.0814

These results show that under the same conditions of concentration and acidity the stannic chloride begins to decompose when reaching a certain concentration, which is the same for all the temperatures tried. The volume of liquid remaining in the flasks was from 2.3 to 2.5 cc.

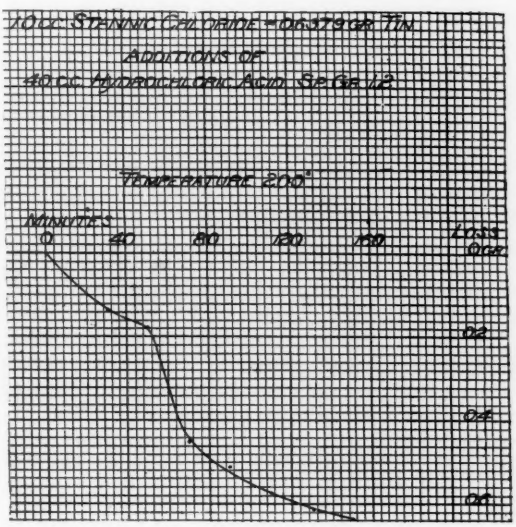
The limit to the loss of tin in all the previous experiments has been the decomposition of the stannic chloride. It seemed reasonable to suppose that by repeated additions of hydrochloric acid the tin

could be completely volatilized. This was shown to be the case. In the following series 10 cc. of the stannic chloride solution were diluted with 40 cc. of strong hydrochloric acid and evaporated to dryness at a temperature of 200°. The residue was dissolved in hydrochloric acid and the loss of tin determined. To other flasks 40 cc. of hydrochloric acid were added after each evaporation to determine the number of evaporations and additions of acid to volatilize the tin completely.

10 cc. stannic chloride containing 0.6379 gram tin. Additions of 40 cc. of hydrochloric acid (sp. gr. 1.2). Temperature 200° C.

	Loss of Tin. Gram.
1st addition	0.1349
2d "	0.1792
3d "	0.4488
4th "	0.5117
5th "	0.5771
6th "	0.6154
7th "	No tin remaining in flask.

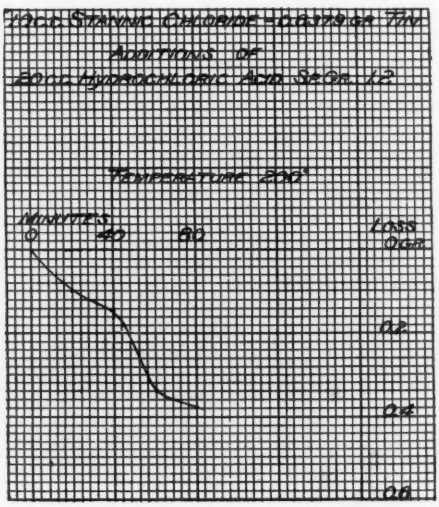
Time, two and one half hours; amount of hydrochloric acid, 280 cc.



In order to determine if smaller additions of acid would accomplish the same result, a series of evaporations was made like the foregoing, except that 20 cc. of acid were added instead of 40 cc.

10 cc. stannic chloride containing 0.6379 gram tin. Additions of 20 cc. hydrochloric acid (sp. gr. 1.2). Temperature 200° C.

	Loss of Tin. Gram.
1st addition	0.0999
2d "	0.1421
3d "	0.3392
4th "	0.3775

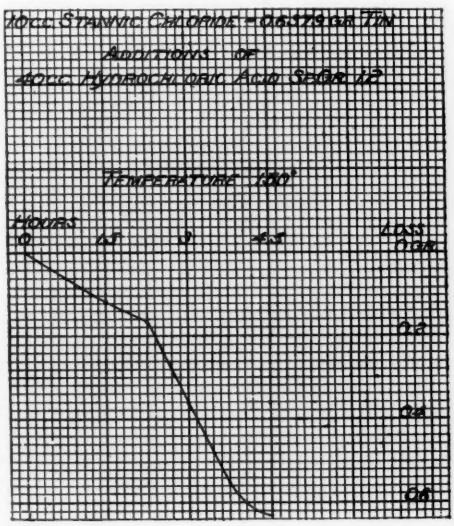


This experiment was not carried to the point of complete volatilization of the tin, since the results obtained showed that the operation would be much prolonged over the time found necessary in the previous experiment, in which 40 cc. of hydrochloric acid were used at each addition.

Nearly as satisfactory results were obtained at 150° as at 200°, as the following results show:

10 cc. stannic chloride containing 0.6379 gram tin. Additions of 40 cc. hydrochloric acid (sp. gr. 1.2). Temperature 150° C.

	Loss of Tin. Gram.
1st addition	.1130
2d "	.1607
3d "	.3629
4th "	.5520
5th "	No tin remaining in flask.



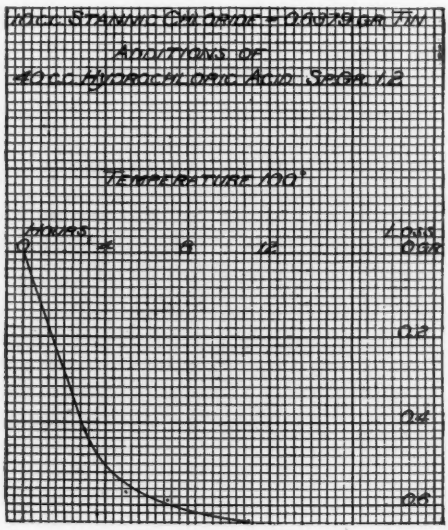
In this case the time required for complete volatilization of the tin was four and one half hours, nearly twice as long as at a temperature of 200°; but the amount of hydrochloric acid required was much less, namely 200 cc.

Experiments were next tried to determine how long a time would be required to volatilize the same amount of tin at the temperature of

the steam bath. These experiments were made in casseroles, and it may be that they are for this reason not strictly comparable with those made in flasks, on account of the possible condensation of the stannic chloride in the neck of the flask.

10 cc. stannic chloride containing 0.6379 gram tin. Additions of 40 cc. hydrochloric acid (sp. gr. 1.2). Temperature 100° C.

	Loss of Tin. Gram.	Time of Evaporation. Hours.
1st addition	0.4195	3
2d "	0.5665	5
3d "	0.5890	7
4th "	0.6214	9
5th "	No tin remaining in casserole.	11

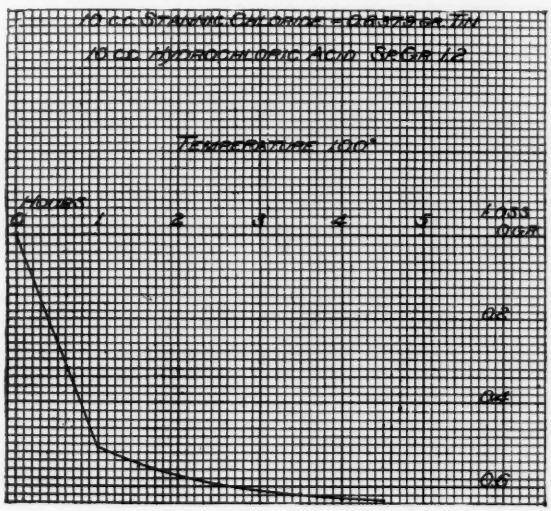


It thus took eleven hours under these conditions for the complete volatilization of 0.6379 gram tin at a temperature of the steam bath, although more than half of the tin was volatilized in the first evaporation when the solution of tin was concentrated.

All of the foregoing experiments point to the fact that the concentration of the solution of stannic chloride is a more important element in the volatility of the tin on evaporation than the amount or strength of hydrochloric acid present. In the following series of experiments the effect of concentration of the tin solution is still more strikingly shown:

10 cc. stannic chloride containing 0.6379 gram tin, evaporated to dryness, and then additions of 10 cc. hydrochloric acid (sp. gr. 1.2). Temperature 100° C.

	Loss of Tin. Gram.	Time of Evaporation. Hours.
1st evaporation	0.5097	1
1st addition of acid	0.5533	1½
2d " "	0.5738	2
3d " "	0.5963	2½
4th " "	0.6115	3
5th " "	0.6187	3½
6th " "	0.6300	4
7th " "	No tin remaining in casserole.	4½

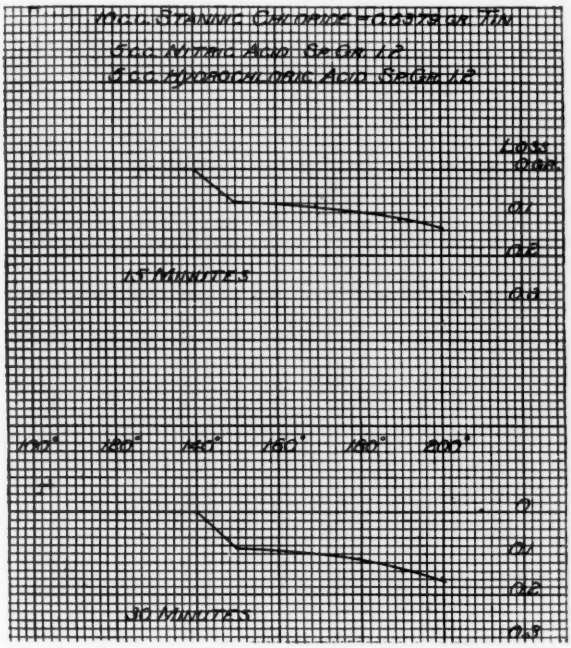


In each evaporation in this series the bulk of solution was only 10 cc., whereas in the previous series the bulk was 40 cc., and the time required for complete volatilization of the tin was thereby reduced from eleven to four and one half hours.

The effect of nitric acid on the volatility of stannic chloride was observed in one series of experiments. It tends to reduce the loss of tin, probably by the earlier formation of the hydrate. Following were the results obtained:

10 cc. stannic chloride containing 0.6379 gram tin, 5 cc. hydrochloric acid (sp. gr. 1.2) and 5 cc. nitric acid (sp. gr. 1.2).

Temperature. Centigrade.	Time. Minutes.	Loss of Tin. Gram.
140	30	None.
150	15	0.0792
150	30	0.0859
160	15	0.0814
160	30	0.0913
170	15	0.0859
170	30	0.1052
180	15	0.1011
180	30	0.1131
190	15	0.1177
190	30	0.1434
200	15	0.1320
200	30	0.1540



It will be noticed that in the presence of nitric acid not only does the loss of tin not begin until a temperature of 150° is reached, but that the difference between the fifteen and thirty-minute heating is much less than when hydrochloric acid only is present.

Finally, an attempt was made to make use of this volatility of stannic chloride in the separation of tin from other metals. Experiments were made with one metal only, namely, lead; and the separation was in this case quite satisfactory. To 10 cc. of the tin solution in a casserole was added a solution of lead chloride and 40 cc. of strong hydrochloric acid. This was evaporated to dryness. After four additions of 40 cc. of hydrochloric acid and evaporations to dryness, the tin was found to be completely volatilized. In four experiments the

amount of lead in the residue was found to be very nearly the same as the amount taken. Following are the determinations of the lead :

	Lead taken. Gram.	Lead found. Gram.
1	0.2324	0.2327
2	0.0942	0.0949
3	0.0897	0.0890
4	0.1794	0.1778

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BOOKS RECEIVED.

Peters, Edward Dyer, Jr. Modern American methods of copper-smelting. Ed. 2 enl. x, 398 p. il. O. N. Y., Scientific Publishing Co., 1891. cl. $4.00.

Wyatt, Francis. Phosphates of America. Where and how they occur; how they are mined; and what they cost. Ed. 2. 187 p. il. O. N. Y., Scientific Publishing Co., 1891. cl. $4.00.

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Nicholl, T. J., comp. Useful information and data for travelers, railway men and mechanics. Ed. 2. 69 p. T. Chicago, Danks & Co., 1892.

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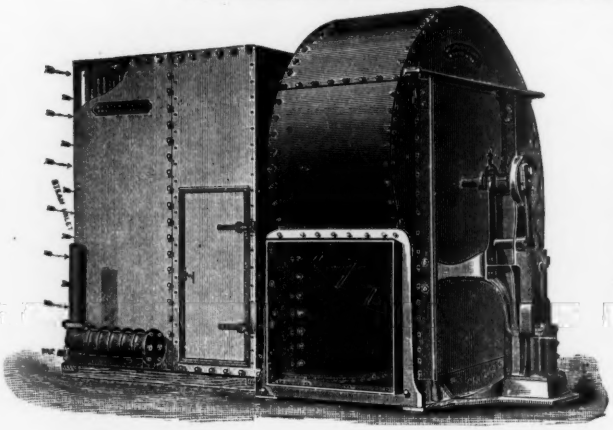

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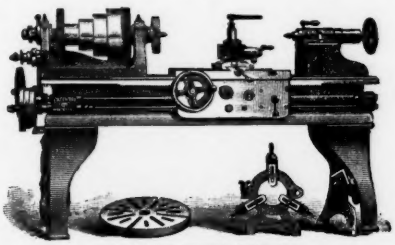

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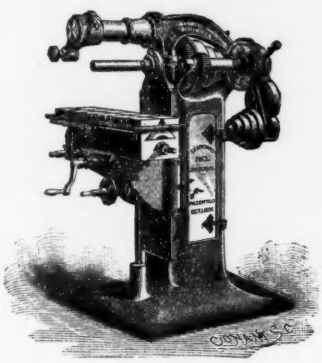

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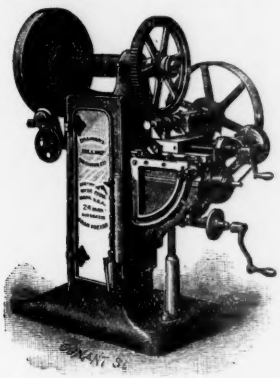

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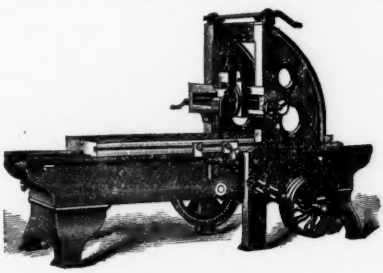

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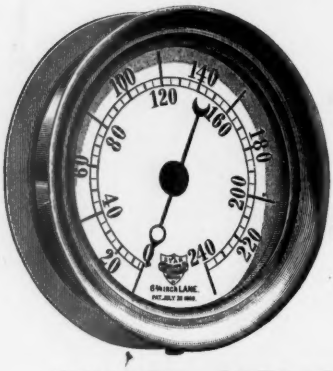

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